PHYSICAL CHARACTERIZATION TECHNICAL MEMORANDUM FOR THE WEST LAKE LANDFILL OPERABLE UNIT 2 BRIDGETON, MISSOURI

VOLUME I: TEXT AND TABLES

Prepared for:

LAIDLAW WASTE SYSTEMS INC.

Prepared by:

Golder Associates

ct No. 943-2848

August 19

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November 5, 1996

Our Ref: 943-2848

Mr. Steven Kinser
US Environmental Protection Agency
Region VII
WSTM/SPFD/REML
726 Minnesota Avenue
Kansas City, Kansas 66101

RE: RESPONSES TO EPA COMMENTS ON THE "PHYSICAL CHARACTERIZATION TECHNICAL MEMORANDUM", WEST LAKE LANDFILL OPERABLE UNIT 2 RI/FS

Dear Mr. Kinser:

This letter provides responses to comments made by the US Environmental Protection Agency (EPA) on the above-referenced document. EPA comments were provided in a September 27, 1996 letter.

The following responses to EPA comments are submitted on behalf of Laidlaw Waste Systems, Inc. (Laidlaw). The EPA comments are reproduced verbatim and are followed by a detailed response. It is understood that the EPA comments include a page number and section number reference.

The text of the memorandum has been changed as indicated in each individual response.

Comment No. 1: *1-3/1.4 - For clarity, a comma should be placed between groundwater and surface water in the third line of this section's first paragraph.*

Response: The suggested revision has been made.

Comment No. 2: *2-3/2.3 - The phrase "which was formed" should be changed to "which were formed" in the third line on this page.*

Response: The suggested revision has been made.

Comment No. 3: *2-3/2.3 - In the last and next to the last paragraph of this section, the term "slow" is used to describe the permeability of the soil. It would probably be more accurate to use the word "low" instead.*

Response: As stated on page 2-2, Section 2.3 is based on information presented by the US Soil Conservation Service (SCS). The SCS uses the term "slow" when describing the permeability of the Freeburg unit. The sentence has been revised to more clearly indicate that the term "slow" is an SCS designation.

Comment No. 4: 2.4 - General - The word 'series' is usually capitalized when it follows a specific formation name, as it has been done in Section 4.1.

Response: The text has been revised to capitalize "series" when it follows a specific formation name.

Comment No. 5: 2-4 / 2.4.1 - Should not the reference in the third line of the second paragraph on this page be Kinderhookian Series rather than Formation?

Response: The reference has been changed to Kinderhookian Series.

Comment No. 6: 2-6 / 2.5.1 - The fourth line of the second paragraph on this page should read, "Mississippian-age Meramecian Series" rather than 'series formations'.

Response: The suggested revision has been made.

Comment No. 7: 2-6 / 2.5.1 - In the third paragraph the reference to the shale would probably be more clear if it were written, "The Ordovician-age Maquoketa shale of the Cincinnatian-series, underlying these systems,".

Response: The suggested revision has been made.

Comment No. 8: 3-6 / 3.2.1 - In the second paragraph when describing the disposable gloves, the word new is enclosed in parentheses. In the following sentence, the description of the plastic sheeting also includes the word new, but it is not enclosed in parentheses. I would assume that the first instance indicates that the option of using either 'clean' or 'new' gloves was given while in the second the only choice was to use 'clean new' plastic sheeting. If this is correct, no change is necessary.

Response: The sentences have been revised to include the word "clean" without reference to "new" and without parentheses.

Comment No. 9: Figure 3-2 - This figure shows that the screened interval of the borehole has been grouted with a cement/bentonite grout. My assumption is that this is not the case. This is not the only problem with the figure; additional modifications will be necessary to complete the figure. I am enclosing a copy of the figure with some suggested modifications. These should guide you in redrafting the figure to show what was actually constructed. It would be beneficial for a well construction diagram for each well to be used in the *monitoring system to be included, or at least a table of elevations for the various elements to provide specific details as to the construction of each well in the monitoring system, and a figure showing a typical long-screened interval Piezometer.*

Response: Figure 3-2 has been revised to incorporate the suggested changes and to ensure consistency with actual construction.

Well construction diagrams for all piezometers installed as part of the OU-2 RI/FS are provided in Volume III, Appendix E. Table 3-3 of the report details OU-2 piezometer locations and pertinent elevations, including top of PVC casing, ground surface, and bottom and top of screened interval.

Long-screened piezometers differ from other recently constructed piezometers only with regard to screen length. Notations have been added to Figure 3-2 stating that screen lengths are detailed in Appendix E.

Comment No. 10:* *Table 3-3 - General* - *I assume that all data taken for this table were available to the nearest 1/100th of a foot since the majority of the data are reported that way. For consistency, all data should be reported to the nearest 1/100th of a foot. The table should also include a note detailing which reference system was used for both horizontal and vertical data.

Response: The suggested revisions have been made. Ground surface data were reported to the nearest 1/10th of a foot, due to variable ground terrain.

Comment No. 11:* *3.2.2.1 - General *- It is unclear what the annular space above the bentonite seas is backfilled with. Figure 3-2 indicates bentonite grout was used, but that figure appears to be unreliable.*

Response: The revisions to Figure 3-2 discussed in EPA comment No. 9 above provide consistency between the text and the figure.

Comment No. 12:* *3.2.6.1 - General *- A minor editorial comment. This section shifts tense from the past, as used in previous sections, to the present tense.*

Response: Section 3.2.6.1 used the present tense when describing water level monitoring because this type of monitoring was continuing at the time the "Physical Characterization Technical Memorandum" was submitted. Subsequent to submittal of the memorandum, water level monitoring requirements have been met and the monitoring has been discontinued. The text has now been revised to use past tense verbs.

Comment No. 13:* *4-4 / 4.1.1.3 *- The second paragraph is slightly confusing. Perhaps it could be restated to say that "fractures were rare with zero to two fractures per foot."*

Response: The second paragraph has been revised as follows: "Fractures were rare in the Salem Formation. The lower portion of the formation generally exhibited zero to one fracture per foot. The upper portion of the formation generally exhibited up to two fractures per foot. The fractures were characterized as jointed, irregular, and rough; or, as jointed, planar, and smooth."

Comment No. 14:* *4-14 & 15 *- These two sections on the Deep Salem Formation and the St. Louis/Upper Salem Formation concluded that ground water flow is towards the active landfill, and I have no argument with that, as far as it goes. Data from the northern and western portion of the site have not been collected that would allow the same conclusion for that area. There is the potential for a ground- water divide similar to the one observed in the unconsolidated material to be present. This needs to be addressed.*

Response: The text has been revised to incorporate the phrase "near the active landfill" when referring to direction of groundwater flow within the Deep Salem Formation and St. Louis/Upper Salem Formation.

It is agreed that a groundwater divide may be present within the Deep Salem Formation and St. Louis/Upper Salem Formation at some distance from the active landfill, as a result of the inferred gradient reversal caused by limestone quarrying and leachate pumping. However, available hydrogeologic data do not appear to warrant additional piezometers in the Deep Salem Formation and St. Louis/Upper Salem Formation in the northern and western portions of the site. The alluvial thickness in these areas is in excess of 100 feet. Any groundwater impacts, should they occur, would be detected by monitoring the alluvial groundwater. Operable Unit 1 has completed groundwater quality sampling of the alluvial groundwater in the northern and western portions of the site. Operable Unit 2 has proposed additional alluvial groundwater quality sampling in the western portion of the site. These data can be used to characterize potential impacts to groundwater quality that can then be used to determine the need for supplemental monitoring points, if any.

Comment No. 15:* *4-28 / 4.3.1 *- This section makes a conclusion that is probably true, but is not specifically supported by the data provided in Table 34. Basin-wide precipitation certainly would have the stated effect, but local precipitation may or may not have the same effect. Note particularly that in November precipitation and river stages are trending in opposite directions.*

Response: The text of Section 4.3.1 has been revised to more clearly discuss the potential relationship between site precipitation and Missouri River stage.

Comment No. 16:* *4-29 / 4.3.2 *- Is there a source of data to support the statement that precipitation falling into the active landfill is estimated to contribute an average of about 99,000 gallons per day? If so, it would be helpful to include that information in the report.*

Response: The estimate of precipitation recharge is based on a mathematical computation. The computation is based on known data, including an approximate 36-acre active landfill footprint and 37-inches of precipitation per year at the site. Conservatively assuming no evaporation, and recognizing that no runoff can occur from the currently below-grade active landfill, 37-inches of precipitation falling on a 36-acre landfill yields approximately 99,000 gallons per day of leachate.

The text has been revised to more clearly indicate the method used to determine 99,000 gallons per day of leachate generated from precipitation.

Comment No. 17: 5-2 / 5.2 *- In the last sentence in the second paragraph in this section, the word 'units' should be replaced with 'formations' and the word 'formations' dropped from 'series formations' and Series capitalized.*

Response: The suggested revisions have been made.

Comment No. 18: 5-5 / 5.4 *- Would it be more accurate to use the term 'deep Salem, St. Louis/Upper Salem' instead of the term "Salem, St. Louis' in the fourth line of this section?*

Response: The suggested revisions have been made.

Comment No. 19: 6-1 / 6.1 *- Would it be more accurate to use the term "St. Louis' rather than "St. Louis/Upper Salem' in the seventh line of the first paragraph of this section?*

Response: It is considered more appropriate to revise the sentence to read "Groundwater monitoring for the alluvial and upper two bedrock hydrologic units (i.e., St. Louis/Upper Salem Formation and Deep Salem Formation) is proposed." The text has been revised accordingly.

Comment No. 20: 6 - General *- The proposed monitoring network does not appear to be monitoring the northern portion of the Site. In addition, there appears to be only one monitoring well to the west of the observed groundwater divide. Leachate monitoring well LR-102 is not included in the monitoring system; is there a reason for this? Why were none of the existing wells used in developing the characterization?*

Response: Figure 6-1 illustrates the proposed monitoring network. As shown on Figure 6-1, groundwater quality in the northern portion of the site is proposed to be monitored by piezometers PZ-208-SS, PZ-114-AS, and monitoring wells I-68, S-84, D-85, I-67, I-66, MW-F3, D-13, and I-65. Piezometer PZ-208-SS has not previously been sampled. Piezometer PZ-114-AS and monitoring wells I-68, S-84, D-85, I-67, I-66, MW-F3, D-13, and I-65 were included in Operable Unit 1 sampling. Accordingly, groundwater quality data will be available from 10 points spaced across the northern portion of the site.

Figure 6-1 illustrates 16 monitoring wells and piezometers (i.e., S-8, I-62, D-83, MW-101, I-7, D-6, S-61, I-2, S-1, D-93, I-9, S-82, MW-103, PZ-304-AS, PZ-304-AI, and PZ-303-AS) along the western portion of the site. Fourteen of the monitoring wells and piezometers were included in Operable Unit 1 sampling. These data are proposed to be supplemented with four additional groundwater sampling points as part of the Operable Unit 2 RI/FS. These data should provide excellent coverage of groundwater quality on the western portion of the site.

Leachate riser LR-102 is not included in the proposed monitoring network because the leachate thickness in LR-102 has consistently been approximately six inches or less. Leachate riser LR-102 is not expected to yield sufficient leachate for sampling. The text has been revised accordingly.

Data obtained from the existing wells has been used throughout the physical characterization of the site. As discussed above, Operable Unit 2 has proposed to incorporate groundwater quality data from existing wells and piezometers sampled by Operable Unit 1 to provide site-wide groundwater quality information, when combined with the proposed Operable Unit 2 sampling points. As shown on Figure 4-1, existing monitoring well MW-F1D was used to assist in developing a geologic cross-section for the site. Water level data from all existing wells and piezometers have been collected on a monthly basis and have been used to develop water table maps to illustrate groundwater flow directions at the site. In summary, the existing wells and piezometers have been referenced extensively when characterizing the physical conditions at the site.

Figure 6-1 has been revised to more clearly identify the OU-1 monitoring wells.

Miscellaneous EPA Comment: There is significant need to further explain the rationale of the proposed monitoring system, particularly that portion of the system that was not included.

Response: Response to EPA comment No. 20 above indicates that groundwater sampling is proposed to be conducted on all sides of the site. Groundwater quality sampling is proposed to be conducted in the alluvium, the St. Louis/Upper Salem hydrologic unit, and the Lower Salem hydrologic unit to determine groundwater quality horizontally and vertically at the site. Operable Unit 2 proposes to collect groundwater quality samples from 24 wells and piezometers, eight leachate risers, two surface water locations and two sediment locations. In summary, 36 Operable Unit 2 locations are proposed for chemical characterization. The 36 Operable Unit 2 sampling locations are supplemented with data available from 28 wells and piezometers sampled by Operable Unit 1. In total, Operable Unit 1 and Operable Unit 2 sampling results will be available from 54 separate sampling locations spread across the entire site. Rainwater/runoff samples, seep samples, landfill gas samples, etc. are also included in the Operable Unit 1/Operable Unit 2 site characterization activities.

The extensive, widespread sampling points are considered sufficient to yield appropriate data for characterizing site environmental conditions, for use in risk assessment determinations, and for evaluating remedial alternatives as part of the feasibility study phase of the project.

We trust that these responses adequately address the comments. To facilitate incorporation of the responses, enclosed is a complete text of the report, along with revised Table 3-3, and revised Figures 3-2 and 6-1. Please replace the previous text with the attached text, and replace Table 3-3, Figure 3-2, and Figure 6-1 with the attached. All other information presented in the original submittal remains current.

Groundwater, surface water, sediment, and leachate sampling activities will await EPA's concurrence with the monitoring network to allow EPA the opportunity to evaluate the responses provided above and the text revisions.

Sincerely,

GOLDER ASSOCIATES INC.

Ward Herst

Ward E. Herst, PE, CPHG, CEM
Operations Manager - St. Louis
Associate

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epa.doc

Attachments

cc: Jalal El-Jayyousi - MDNR
Doug Borro - Laidlaw Waste Systems
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PHYSICAL CHARACTERIZATION TECHNICAL MEMORANDUM
FOR
WEST LAKE LANDFILL OPERABLE UNIT 2
BRIDGETON, MISSOURI

VOLUME I

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VOLUME 1

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1.0 INTRODUCTION

1.1 Purpose

Golder Associates Inc. (Golder) was retained by Laidlaw Waste Systems, Inc. (Laidlaw) to perform a Remedial Investigation and Feasibility Study (RI/FS) at Operable Unit 2 of the West Lake (Bridgeton) Landfill, Bridgeton, Missouri. This report presents the results of field activities performed by Golder to identify the physical characteristics of the site. The investigation was performed in accordance with the EPA-approved *Remedial Investigation/Feasibility Study Work Plan, West Lake Landfill Operable Unit 2, Bridgeton, Missouri* (Golder, 1995a), and the EPA-approved *Remedial Investigation/Feasibility Study Work Plan Appendix A,* (Golder, 1995b). This Physical Characterization Memorandum provides the following information:

- Reviews of investigative activities;
- Describes and displays data documenting the location and characteristics of surface and subsurface features; and,
- Recommends a groundwater quality monitoring network.

1.2 Background

The West Lake (Bridgeton) Landfill site is a 212-acre facility located within the City of Bridgeton, St. Louis County, Missouri (Figure 1-1). The site address is 13570 St. Charles Rock Road (Figure 1-2). The site includes an active solid waste landfill, an inactive demolition landfill, an inactive landfill, concrete and asphalt batch plants, an automobile repair shop, and a former telephone switching station (Figure 1-3). The site was used agriculturally until 1939, when a limestone quarry and crushing operation (described in Section 1.3) was initiated. Current ownership for the West Lake Site is depicted in Figure 1-4.

1.3 Site Description

As shown in Figure 1-2, the West Lake Site is bordered on the north by St. Charles Rock Road (State Highway 180), and on the east by Taussig Road and agricultural land. Old St. Charles Rock Road, along with undeveloped land, borders the southern and western portions of the site. Property north of the site (across St. Charles Rock Road) is moderately developed with commercial retail and manufacturing operations. The Earth City industrial park is adjacent to the site on the west (across Old St. Charles Rock Road). Surrounding area zoning and land use is depicted in Figure 1-5.

The site is located on the eastern edge of the Missouri River floodplain. The Missouri River is located approximately two miles west of the site. The area is transitional between the alluvial floodplain immediately to the west and the loessial bluffs 0.5 miles to the east. The edge of the alluvial valley is oriented north to south through the center of the site (Figure 1-3). Topography in the area is gently rolling. However, the site topography has been significantly altered by quarry activities in the eastern portion, and placement of mine spoils (unused quarry rock) and landfilled materials in the western portion.

The limestone quarry was operated between 1939 and 1988, and was closed when economically-recoverable reserves were exhausted. The quarry consists of two pits which were excavated to a maximum depth of about 240 feet below ground surface (bottom elevation of about 240 feet above mean sea level, MSL). The active sanitary landfill is operated within the former limestone quarry. Landfilling operations were initiated within the north pit of the quarry in 1979. Landfilling in the north pit terminated at a maximum elevation of about 500 feet MSL. Currently, active landfilling is taking place in the south pit, which is filled with solid waste to a depth of about 100 feet below ground surface (380 feet MSL elevation).

The landfill has been constructed with a gas collection system and a separate leachate collection system. The gas collection system is designed to alleviate potential odor problems and recover gas for potential beneficial use. The leachate collection system is of hydrogeologic importance because it is designed to remove surface water and groundwater which flow into the active sanitary landfill. The leachate collection system therefore acts as a groundwater sink to the aquifers surrounding the active landfill. The leachate collection system currently includes four leachate collection sumps, LCS-1 through LCS-4 (Figure 1-6), fitted with pumps which discharge pumped leachate to an adjacent lined retention and aeration pond (referred to as the "Leachate Retention Pond"). The sumps are located near the four corners of the south pit, and extend from the active sanitary landfill surface to the pit floor. In accordance with terms of the landfill permit, the sump pumps are typically activated to maintain a maximum 30 feet of leachate head in the landfill. Based upon hydrogeologic conditions, the leachate head level could be raised to about 60 feet and still maintain an inward hydraulic gradient that is protective of the environment. Based on Laidlaw records for 1994, the leachate collection system collects an average of about 216,500 gallons of leachate per day from the active landfill area. Two additional leachate collection sumps have been installed in the north pit. These sumps have not been pumped to date and do not affect leachate or groundwater conditions. The collected leachate is pumped to the leachate pond for treatment and subsequent discharge to the St. Louis Metropolitan Sewer District (MSD).

1.4 Scope of Work

The objective of the physical characterization investigation was to characterize the site surface and subsurface features, as well as identify potentially impacted areas, and identify appropriate groundwater, surface water, sediments, and leachate sampling locations. The investigation included:

- A desk study and literature review (collection and review of relevant historical and background data and information);

- Detailed geologic mapping of the exposed quarry walls to allow comparison of large-scale geologic features to the geology obtained from the boreholes;

- The advancement and sampling of soil, bedrock, and solid waste in 56 borings. Eleven borings were advanced into the shallow alluvium, three borings were advanced into the intermediate depth alluvium, two borings were advanced into the deep alluvium, four borings were advanced into the solid waste, 28 borings were advanced into the St. Louis and upper Salem Formations, four borings were advanced into the deep Salem Formation, and four borings were advanced into the Keokuk Formation. Total footage drilled was over 6,000 feet, and included nearly 1,600 feet of soil sampling and 3,300 feet of rock coring;

- Geotechnical testing of soil and rock samples;

- Chemical analysis of soil samples;

- Borehole geophysical logging in designated borehole locations;

- Packer testing of 49 separate intervals in seven boreholes;

- Installing piezometers in the 53 boreholes, constructed to monitoring well specifications in accordance with *Missouri Private Water Well, Heat Pump System, Pump Installation and Monitoring Well Construction Rules* (MDNR, 1993);

- Installing two-inch diameter PVC casing in existing monitoring well MW-1201 (renamed PZ-1201-SD), which had originally been completed as an open-borehole monitoring well;

- Installing three leachate risers into solid waste;

- Developing and slug testing each of the piezometers;

- Periodically measuring groundwater levels in each piezometer and leachate riser; and,

- Periodically measuring surface water levels in site surface water bodies.

2.0 REGIONAL GEOLOGY AND HYDROGEOLOGY

2.1 Topography

The site is situated within the western portion of the St. Louis metropolitan area in northeastern St. Louis County. Located at the confluence of the Missouri and Mississippi Rivers, the St. Louis metropolitan area consists of Jefferson, St. Charles, and St. Louis counties in Missouri, as well as adjacent counties in Illinois (Figure 1-1). The northeastern two thirds of St. Charles and St. Louis counties, and the extreme northeastern part of Jefferson County, lie within the Dissected Till Plains of the Central Lowland physiographic province (Miller et al., 1974).

The gently undulating Dissected Till Plains range in elevation from about 450 to 700 feet MSL. The area was glaciated twice during the Pleistocene era, but the morainal topography typical of adjacent glaciated areas is not present. The till deposits are thin and dissected due to post-Pleistocene erosion.

2.2 Surface Water Hydrology

Three major rivers, the Mississippi, the Missouri, and the Meramec, pass through the region and supply nearly all of the water used in the St. Louis area (Emmett and Jeffrey, 1968). The Mississippi River flows to the south along the eastern Missouri state border. The Missouri River generally flows to the east across Missouri through the western and northern portions of the metropolitan area and discharges into the Mississippi River north of St. Louis. Near the site, the Missouri River flows in a predominantly northerly direction. The Meramec River flows along the southern portion of the metropolitan area and discharges into the Mississippi River south of St. Louis. Other minor rivers and streams in the area are tributaries to these three rivers. A few other minor surface water features (such as lakes) are present in the St. Louis metropolitan area.

The present channel of the Missouri River lies about two miles west and northwest of the site. Historic land surveys indicate that approximately 200 years ago the channel was several hundred yards east of its present course (Banerji et al., 1984). The Missouri River has a surface slope of 0.00018 feet per foot. The reference river stage at St. Charles (upstream and west of the site), Mile 28, is 413.7 feet MSL. Average discharge for the Missouri River is 77,300 cubic feet per second (cfs), with a typical minimum flow of about 40,300 cfs in December and January and a typical maximum flow of about 100,750 cfs in April through July.

Precipitation that falls into the Missouri River floodplain generally infiltrates the alluvial deposits. The floodplain is relatively flat, and the sediments have an infiltration index of 3.5 inches (Miller et al., 1974). Streams present within the floodplain originate in the surrounding uplands.

Drainage patterns within the floodplain west of the site have been altered by flood control measures taken to protect nearby commercial development, and by the drainage of local swamps and marshes. Before these alterations, Creve Coeur Creek flowed just south of the site along Old St. Charles Rock Road. A stormwater retention pond encompassing a portion of the old Creve Coeur Creek channel is present west of the site, adjacent to the Earth City industrial park.

2.3 Soils

According to the US Soil Conservation Service (SCS), surficial materials along the floodplain of the Missouri River generally consist of the Blake-Eudora-Waldron association, while the surficial materials on bluffs east of the river are the Urban Land-Harvester-Fishpot association (SCS, 1982). The floodplain materials are described as nearly level, somewhat poorly drained to well drained, deep soils formed in alluvial sediment. The upland materials are urban land and nearly level to moderately steep, moderately well drained to somewhat poorly drained, deep soils formed in silty fill material, loess, and alluvium, which were formed on uplands, terraces, and bottom lands.

Soils in the immediate vicinity of the site consist of the Freeburg-Aston-Weller association, which are nearly level to gently sloping, somewhat poorly drained to well drained, deep soils formed in loess and alluvial sediment. The Freeburg silt loam is found on the terrace adjacent to the eastern site boundary, while the Ashton silt loam is found to the east and south of the south pit (including the current active landfill borrow area).

The Freeburg unit is identified as a somewhat poorly drained silt loam to silty clay loam, up to 60 inches thick. Permeability of this soil is characterized by the SCS as moderately slow (about 10^{-4} centimeters per second, cm/sec), and the surface runoff is medium. According to the SCS, a perched water table is often present within this unit in the spring, at a depth of 1.5 to 3 feet. The Freeburg unit's suitability for landfill daily cover is described as fair, due to the clay content (12 to 35 percent) and wetness.

The Ashton unit is a well drained silty loam to silty clay loam, also up to 60 inches thick. Permeability of this unit is also moderately slow, and the surface runoff is medium. The suitability of the Ashton unit for landfill daily cover is described as fair, due to the clay content (10 to 40 percent).

2.4 Regional Geology

2.4.1 Bedrock

The bedrock stratigraphic sequence in the St. Louis area consists primarily of limestone, dolomite, and shale. Geologic deposits range in age from Precambrian to Quarternary-

Holocene. A generalized stratigraphic column for the St. Louis area is presented in Table 2-1.

Precambrian igneous and metamorphic rocks underlie Cambrian units, which consist of cherty dolomite, siltstone, sandstone, and shale. Overlying Ordovician deposits may be up to 2,300 feet thick and are primarily limestone, dolomite, and shale with some sandstone. Cherty limestones of Silurian age overlie the Ordovician deposits, and are up to 200 feet thick. Devonian units lie unconformably on the Silurian deposits, and consist of sandstone, limestone, and shale deposits up to about 100 feet thick.

The uppermost significant bedrock units in the region are the Mississippian System Kinderhookian, Osagean, and Meramecian Series. These formations consist primarily of limestone with some shale and siltstone. The Kinderhookian Series is an undifferentiated limestone, dolomitic limestone, shale, and siltstone unit ranging in thickness from 0 to 122 feet. The Osagean Series consists of the Fern Glen Formation (a red limestone and shale) and the Burlington-Keokuk Formation (a cherty limestone). The Fern Glen Formation ranges in thickness from 0 to 105 feet and the Burlington-Keokuk Formation (herein after referred to as the Keokuk) from 0 to 240 feet. The overlying Meramecian Series includes the Warsaw Formation (0 to 110 feet thick), the Salem Formation (0 to 180 feet thick), the St. Louis Formation (0 to 180 feet thick), and the St. Genevieve Formation (0 to 160 feet thick). The uppermost bedrock unit beneath the majority of the site is the St. Louis Formation. The St. Genevieve Formation is not present. In the southeast corner of the site, in the borrow area, the Cheltenham Formation was identified. Recently published information indicates that Cheltenham Formation was deposited prior to Pennsylvanian time and ranges in age from Atokan to latest pre-Marmaton (Thompson, 1995). The Keokuk, Warsaw, Salem, and St. Louis Formations were characterized in the recent site characterization investigation.

Pennsylvanian-age Missourian, Desmoinesian, and Atokan Formations are present in some areas above the Mississippian System. These units consist primarily of shale, siltstone, and sandstone with silt and clay, range in thickness from 0 to 375 feet.

2.4.2 Unconsolidated Materials

Quarternary deposits in the region are comprised of recent (Holocene) alluvial deposits from the Missouri River, and upland loess and glacial till deposits from Pleistocene glaciation. The alluvial deposits range in thickness from 0 to 150 feet. Loessial deposits are up to 110 feet thick, and glacial till deposits are infrequent but occur in layers up to 55 feet thick. Near the site, the overall thickness of the alluvium varies from 0 feet at the contact with the loess immediately east of the site to approximately 100 feet beneath the center of the Missouri River valley, 2 miles west.

The loess is an aeolian (windblown) deposit and consists primarily of silt and clay. The loess was deposited as a blanket over much of northern Missouri and Illinois during the Pleistocene glacial epoch. The bluffs and hills immediately east of the site are composed of loess in deposits up to 80 feet thick.

Both alluvium and loess were encountered during the OU-2 remedial investigation. The areal extent of the two unconsolidated units is discussed in Section 4.1.2.

2.5 Regional Hydrogeology

2.5.1 Regional Aquifers

Groundwater is present in the region in both unconsolidated materials (alluvium) and bedrock, as described below.

The major alluvial aquifers in the area are differentiated to include the Quarternary age alluvium and the basal parts of the alluvium underlying the Missouri River floodplain. These floodplain alluvial aquifers are typically exposed at the surface and can be as much as 150 feet thick (Miller et al., 1974).

Bedrock aquifers in the St. Louis area which are favorable for groundwater development include Ordovician-age St. Peters Sandstone, Roubidoux Formation, and Gasconade Dolomite, as well as Cambrian-age Potosi Dolomite (Miller et al., 1974). The Mississippian-age Meramecian Series immediately underlying and adjacent to the West Lake Landfill site (including the Warsaw, Salem, and St. Louis Formations) are not identified as favorable for groundwater development (i.e., yield less than 50 gallons per minute [gpm] to wells) (Miller et al., 1974).

Miller (et al., 1974) describes the uppermost regional aquifers (Pennsylvanian, Mississippian, Devonian, and Silurian) as yielding small to moderate quantities of water, ranging from 0 to 50 gpm. The Ordovician-age Maquoketa shale of the Cincinnatian-series underlying these systems probably constitutes a confining influence on water movement from underlying aquifers favorable for groundwater development. Deeper Ordovician-age and Cambrian-age aquifers described below are considered favorable as non-potable water sources.

The St. Peter Sandstone aquifer lies at a depth of approximately 1,450 feet below ground surface and can be as much as 160 feet thick. The average depth of the Roubidoux Formation is approximately 1,930 feet. Thickness of this unit in the St. Louis area ranges from 0 to 177 feet. The Gasconade Dolomite directly underlies the Roubidoux Formation. The Gasconade and associated Gunter Sandstone occur in thicknesses of up to 280 feet. The Potosi Dolomite can be present in thicknesses of up to 324 feet, at an average depth of 2,240 feet. It should be noted that the thickness and depth to these formations varies throughout the St. Louis area, and they may not be present in some places.

While of regional importance, none of the above aquifers are relevant to the West Lake Landfill site due to their great depths and the overlying Maquoketa shale confining unit.

2.5.2 Regional Wells

Alluvial groundwater wells completed in the Mississippi and Missouri river floodplains are capable of yielding more than 2,000 gpm (Emmett and Jeffrey, 1968). However, no public water supply wells within the vicinity of the site draw from the alluvial aquifer (Foth & Van Dyke, Dec. 12, 1989). In 1989, 26 private water supply wells were identified within a 3-mile radius of the site; no well within a 1-mile radius is used as a drinking water source (Foth & Van Dyke, Feb. 10, 1994). The radial distribution of the 26 private water supply well locations is as follows:

- Four wells located less than one mile from the site. Two no longer exist and the remaining two are not used as a drinking water source;
- Seventeen wells located between one and two miles from the site. Four wells are used for irrigation purposes, one well is at an abandoned site, and twelve wells are used as drinking water sources; and,
- Five wells located between two and three miles from the site. All are used as drinking water sources.

The number of private water supply wells has likely decreased since 1989 due to development and flooding in 1993 and 1995. There are two private groundwater wells within one mile of the site that are used for monitoring or commercial purposes, and none are used for drinking water (Foth & Van Dyke, Feb. 10, 1994). A private groundwater well located at the Old Bridge Bait Shop is 5,100 feet from the site boundary, while a private groundwater "shop well" is located 4,600 feet from the site boundary. The nearest reported well used as a drinking water source is located approximately 5,300 feet north of the site (Figure 2-1).

Wells yielding up to about 50 gpm can be developed in bedrock aquifers overlying the Maquoketa shale described above (Miller et al., 1974). However, the results of the physical characterization indicate that wells completed in the bedrock aquifers underlying the site generally yield very little water (<5 gpm).

3.0 FIELD INVESTIGATION

This section summarizes previous investigations and describes the methods used to conduct the recent OU-2 investigation at the West Lake Site.

3.1 Previous Investigations

Numerous investigations pertaining to hydrogeological and environmental conditions have been conducted at and around the West Lake Site. These investigations focused primarily on environmental conditions originating from inactive portions of the site. However, these investigations include information pertinent to hydrogeologic characterization of the entire site. Additionally, ongoing environmental monitoring of air, soil, surface water, and groundwater is being conducted. A chronological listing and brief summary of the previous investigations performed at the site is provided in Table 3-1.

The most extensive previous hydrogeologic investigation conducted at the West Lake Site was performed by Burns & McDonnell (BMD) of Kansas City, Missouri, in 1986. This investigation was oriented towards the inactive landfill area located on the western portion of the West Lake Site. Boreholes were drilled and monitoring wells installed at shallow, intermediate, and deep depths of the alluvial aquifer. The *Hydrogeologic Investigation, West Lake Landfill, Primary Phase Report* (BMD, 1986) included the following conclusions.

- The alluvium of the Missouri River forms the major aquifer in the vicinity of the site. The underlying bedrock is relatively impermeable, both on the valley side slopes and the bedrock valley buried beneath the alluvium.

- Alluvial deposits of the Missouri River are in hydraulic communication with the river; thus the river has a major influence on water levels in the alluvium. A rise in river stage during seasons of high rainfall and snow melt causes the water table in the aquifer to rise. Conversely, a seasonal drop in the river stage causes the water table in the aquifer to drop. Although the rise and fall of the aquifer is less than that of the correlative change in river stage, the change in water table elevation is relatively uniform throughout the entire extent of the site vicinity.

- The predominant direction of groundwater flow in the alluvial aquifer in the region near the site is northwestward toward the Missouri River. There are broad fluctuations in this flow direction throughout the year and the predominant flow direction ranges from slightly south of due west to northwest.

- Throughout most of its extent, the alluvial aquifer is generally unconfined (under water table conditions). Relatively low-permeability, discontinuous clayey and silty zones in the upper part of the alluvium may cause semi-confined and perched water conditions in very localized areas.

3.2 Recent Investigation

The recent investigation was conducted to satisfy the physical characterization requirements of the *Administrative Order on Consent* for OU-2 (EPA, 1994a). The investigation was conducted in accordance with the EPA-approved OU-2 Work Plan, as detailed in the OU-2 Sampling and Analysis Plan. The investigation was performed by Golder from January 1995 through June 1996. The following paragraphs describe piezometer location rationale; piezometer leachate riser, soil boring designations; and borehole sampling rationale. Subsequent subsections detail the field investigation methodology.

Piezometer Location Rationale

A series of single, paired, and clustered piezometers was installed to evaluate groundwater flow directions and hydraulic relationships in stratigraphic units at the site as well as to determine subsurface physical characteristics. Forty-nine piezometers were drilled, at 33 locations. The 33 locations are on average about 350 feet apart. The piezometers allow for monitoring of hydrogeologic conditions in critical water bearing zones. Selected piezometers were converted to monitoring wells for inclusion in the site groundwater monitoring network, as described in Section 6.0.

The piezometers were designated "100-", "200-", and "300-" series, and characterize unconsolidated (loess and alluvium) and bedrock (Salem, St. Louis, Warsaw, and Keokuk Formations) materials. The "100-" series piezometers are generally placed immediately adjacent to the perimeter of the active sanitary landfill, while the "200-" series piezometers are generally located within 500 feet of the active sanitary landfill. The "300-" series piezometers are placed adjacent to the inactive landfill areas in the western portion of the site, and upgradient of the site. Piezometer locations are provided in Figure 3-1.

For alluvial piezometer pairs and clusters installed in the western portion of the site (where saturated alluvium is present), the piezometers were screened:

- At the water table;
- At intermediate depths within the alluvium; and,
- Immediately above the uppermost bedrock.

Bedrock piezometers were screened:

- Approximately 50 feet into the St. Louis and upper Salem Formations for bedrock piezometers in the alluvial valley, or 10 feet below the water table for bedrock piezometers outside the alluvial valley;
- At the bottom of the Salem Formation; and,
- At the top of the Keokuk Formation.

The deepest borings were drilled into the Keokuk Formation and were completed over 150 feet below the inferred base of solid waste in the active sanitary landfill.

Table 3-2 identifies the rationale utilized for siting each of the piezometers, leachate risers, and soil borings. Table 3-3 summarizes piezometer locations, depths, and screened intervals of subsurface sample points.

Piezometer Designation

Piezometers were identified with the prefix "PZ" and a suffix designation specific to the formation being monitored. An "A" suffix was used if the piezometer was completed in alluvium (unconsolidated materials). An "S" suffix was used if the piezometer was completed in the Salem or St. Louis Formations. A "K" suffix was used if the piezometer was completed into the Keokuk Formation. The piezometer identifiers were further modified with an additional suffix designating whether the piezometer was completed into the shallow ("S" suffix), intermediate ("I" suffix) or deep ("D" suffix) portion of the aquifer. The following is an example of a piezometer designation:

PZ-100-SS

Where:

PZ = piezometer;
100 = "100" series;
The first "S" = completed into the Salem or St. Louis Formations; and,
The second "S" = completed into the upper (shallow) portion of the aquifer.

Leachate Riser Designation

Six leachate risers designated LR-100 through LR-105 were to be drilled in areas where EPA inferred that industrial and/or hazardous wastes may have been disposed (USEPA, 1989; USEPA, 1991). If leachate was encountered in the test borings, a leachate riser was to be installed. The leachate risers were constructed with 2-inch PVC well casing.

Soil Boring Designations

Four soil borings designated as SB-01 through SB-04 were installed to monitor for potential petroleum impact to soils near the southwest corner of the inactive landfill.

Borehole Sampling Rationale

As described above, the boreholes were sited in single, paired, and clustered locations (Figure 3-1). Single boreholes, and, in general, the deepest boreholes at paired or clustered piezometer locations, were sampled continuously to provide stratigraphic control. Shallower boreholes at the cluster locations were sampled across the proposed piezometer screen interval. Accordingly, borehole drilling methodology varied according to sampling requirements. Selected boreholes were logged geophysically and packer tested upon completion of drilling. Piezometers were subsequently installed in certain boreholes, surveyed for location and elevation, developed, and slug tested. Boreholes drilled through solid waste materials in the inactive landfill were completed as leachate risers where leachate was encountered. Other boreholes were backfilled with grout and abandoned. These elements of the subsurface investigation are described in detail in the following subsections.

3.2.1 Subsurface Drilling, Sampling, and Testing

Boreholes were drilled by Layne-Western, Inc. (Layne-Western) of St. Louis, Missouri. Drilling, sampling, and testing were supervised or performed by qualified Golder personnel. Boreholes drilled through unconsolidated materials (i.e., loess, alluvium, fill, or solid waste) were advanced using a Central Mining Equipment (CME) 75 drill rig with hollow stem augers until the target depth was reached or bedrock was encountered. Boreholes drilled through bedrock materials were advanced using the CME 75 or a

Schramm Rotadrill, Model T660H air rotary drill rig with associated rock drilling equipment. All downhole equipment was decontaminated with a high pressure potable water steam cleaner before drilling was initiated at each borehole.

Subsurface samples were collected during borehole drilling to identify the stratigraphic characteristics of unconsolidated materials and bedrock. Sampling equipment was decontaminated with Liquinox™ (or a comparable solution) and rinsed with potable water between each use. After air drying, the equipment was rinsed with distilled or deionized water. All cleaned or unused sampling equipment was handled by personnel wearing disposable latex gloves. The decontaminated sampling equipment was stored in plastic bags or sheeting. As specified in the Work Plan, water used for decontamination activities was disposed of in the leachate retention pond located southwest of the site.

In certain boreholes, where landfilled materials or flowing sands were encountered, surface casings were installed to isolate these materials from underlying aquifers. Surface casings were also installed in certain boreholes drilled into the Keokuk Formation, in order to isolate groundwater in aquifers overlying the low-permeability shales of the Warsaw Formation from groundwater in the underlying Keokuk Formation. Borehole logs (described below), piezometer construction summaries (described in Section 3.2.2), and Table 3-3 identify boreholes constructed with surface casing.

3.2.1.1 Unconsolidated Material Drilling and Sampling

Subsurface drilling in the unconsolidated materials was performed with a CME 75 drill rig. Different drilling and sampling techniques were utilized depending upon the subsurface conditions encountered. The majority of drilling was accomplished with either 4.25-inch or 6.25-inch inside diameter (ID) hollow stem augers. Bentonite mud rotary techniques, utilizing a 3-inch diameter tricone bit, were used if saturated heaving sand deposits were encountered greater than or equal to ten feet in thickness. The bentonite mud was used to stabilize the borehole during drilling and sampling at boreholes PZ-113-AD, PZ-115-SS, PZ-300-AI, PZ-302-AI, PZ-304-AI, and PZ-305-AI. The bentonite mud was mixed and contained in portable mud tanks. Bentonite mud was also used to stabilize the borehole for installation of surface casing in the unconsolidated materials at boreholes PZ-105-SS, PZ-107-SS, PZ-111-SD, PZ-111-KS, PZ-115-SS, PZ-203-SS, PZ-205-SS, and PZ-300-SS. These boreholes were also drilled with 10.25-inch augers to allow for the installation of surface casings.

Selected boreholes proposed in the Work Plan were deleted or moved, after notifying EPA and receiving verbal approval to do so. Representatives of Maryon Industries (Asphalt Plant Operators) would not allow access to drill PZ-305-AS and PZ-305-AI on their leased property. Maryon Industries is currently remediating free product from underground storage tank releases in the area. The borehole for PZ-305-AI was moved further east and adjacent to leachate riser LR-104. PZ-305-AS was not drilled. Leachate riser LR-104 should be considered as a replacement for PZ-305-AS. Piezometer PZ-300-AI discussed in the Work Plan was not constructed because less than five feet of saturated alluvium was encountered above bedrock in adjacent boreholes PZ-300-AD and PZ-300-SS preventing isolation of saturated intervals in the alluvium.

The unconsolidated materials were continuously sampled using standard 1.5-inch ID by 2.0-foot long split spoon samplers. The split spoon samplers were advanced below the augers with either an automatic or semi-automatic hammer dropping system which lifted a 140-pound hammer approximately 30 inches. The number of blows required to advance the sampler in 6-inch intervals over the 2-foot length were recorded. At designated boreholes and intervals, 2 13/16-inch ID/3.0-inch outside diameter (OD) by 2.5-foot long Shelby tube and California barrel were used to collect undisturbed soil samples.

As part of the subsurface investigation, four soil borings were drilled at the southwest corner of the inactive landfill (Figure 3-1). The boreholes were drilled to define the extent of potential hydrocarbon impact to the soils adjacent to existing well MW-F2. The soil borings were sampled continuously with split spoon samplers. The borings were terminated at the water table, which was identified from 13 to 18 feet below ground surface.

Head space analysis of the individual soil sample from the soil borings was conducted to determine if volatile organic compounds were present. The individual soil samples from two foot intervals were immediately placed in jars and sealed. After the borehole was completed and the soil samples had warmed up to ambient air temperature, the air head space over the soil samples in the jars was screened with a MiniRae photoionization detector for volatile organic compounds. The head space readings were recorded on the soil borehole logs (Appendix A). The results of the head space analysis were used to select a soil sample from each of the soil borings to submit for analytical laboratory analyses. If elevated readings were not detected, the soil sample collected nearest the water table was submitted for laboratory analysis.

The selected soil samples were delivered to Quanterra Incorporated under strict Chain-of-Custody procedures. The samples were immediately placed on ice and shipped overnight to the laboratory in sealed coolers.

At the "300" series piezometer boreholes, one sample from the proposed screen interval was collected and analyzed for Total Organic Carbon (TOC), consistent with Work Plan specifications. The samples were collected in brass liners inside a California Barrel sampler. The samples were labeled and immediately placed on ice in a cooler. The samples were delivered to Quanterra Incorporated of North Canton, Ohio, under strict Chain-of-Custody procedures. TOC results will be discussed in the Site Characterization Report to be submitted to EPA at a later date.

All soil samples were photographed, visually described, and then placed in labeled Ziplock™ plastic storage bags. The samples were described according to the Unified Soil

Classification System (USCS) and Golder technical procedures, and descriptions were recorded on soil borehole logs. The logs are presented in Appendix A. The soil borehole logs include the geologic origin (if appropriate), blow counts, sample recovery, color (Munsell Rock Color Chart), material description, and classification according to the USCS using ASTM Methods D2487 and D2489. Figure A-1 identifies USCS classification symbols utilized in the logs.

3.2.1.2 Bedrock Drilling and Sampling

Continuous sampling of the bedrock units was accomplished with the CME 75 drill rig using diamond core drilling techniques. A triple tube, wireline 3.5-inch OD NX core drilling system was used. Shallow bedrock boreholes at paired or clustered locations where continuous sampling was not necessary were drilled with a 5 7/8-inch diameter button air percussion hammer bit to the top of the proposed piezometer screen depth, and then cored across the proposed screen interval. Coring in these boreholes was accomplished with the Schramm air drill rig using a double tube NX coring system. Potable water and/or filtered air were used as the drilling medium to remove the cuttings and advance the borehole.

The record of drillhole logs are provided in Appendix A and include descriptions of the geologic characteristics of the rock core. Graphic logs depict lithology and fracture orientation (relative to the core axis), with discontinuities described according to type, shape, and surface characteristics. Figure A-2 identifies rock symbols utilized in the logs, while Figure A-3 of Appendix A describes the basic characteristics logged by Golder personnel. The rock description used by Golder is as follows:

- WEATHERING - Classification according to International Society for Rock Mechanics (ISRM) standard and qualitative description of any unusual weathering characteristics.

- STRUCTURE - Any persistent structure in rock such as foliation, flow banding, bedding, lamination, grading, sorting, etc., and dip specification with respect to the core axis.

- COLOR - Color name from Geologic Society of America Munsell Color Chart of wet rock. If rock is composed of more than one color, major colors starting with the most prominent are listed.

- GRAIN OR CRYSTAL SIZE - Size of visible grains or crystals in millimeters or according to the Wentworth scale.

- STRENGTH - Field estimate of intact strength based on ISRM classification. Qualitative description of factors that might affect strength such as weak layers and any seams.

- ROCK TYPE - Basic rock type as recognized by Colorado School of Mines Classification System (Travis, 1955).

Geotechnical parameters were also recorded and include core recovery, fracture frequency, rock strength, and Rock Quality Designation (RQD). RQD is a modified core recovery in which only the sound core recovered in lengths greater than four inches (measured along the core axis) is counted as recovery. RQD is expressed as the percentage of total length of intact core recovered in lengths greater than 4 inches over the total length of the core run. The RQD percentage can then be used to describe the rock quality.

Rock core was placed in wooden core boxes after logging. The stratigraphic orientation of the core was indicated, and each core box was labeled with an indelible marker with the project name and/or number, the borehole number, the box number, and the depth at the start and end of the core contained in the box. All rock core was photographed. At the conclusion of drilling, the core boxes were stored in a building at the site.

After the borehole had been drilled to final depth, the borehole was reamed with 5 7/8-inch diameter air percussion button hammer bit using air rotary drilling techniques. The boreholes were reamed to allow downhole geophysical testing, packer testing, and piezometer installation.

Surface casing was used at certain borehole locations to seal off loose or saturated alluvial deposits, isolate saturated flowing sands, or to isolate overlying formations prior to advancing the borehole into underlying formations. Surface casings were not required by the EPA-approved OU-2 Work Plan (Golder, 1995a). Use of surface casings was deemed appropriate to provide additional environmental protection and to ensure representative data. Golder field engineers determined after drilling PZ-100-KS that surface casings would be utilized in subsequent boreholes, where necessary, to isolate formations above the Warsaw Shale before penetrating that unit. Table 3-3 summarizes the surface casing sizes and depths at the individual borehole locations. Surface casing consisted of 20-foot lengths of steel pipe with either 6 1/8-inch ID/6 5/8-inch OD or 10-inch ID/10 7/8-inch OD specifications. The 10-inch ID casing was used in conjunction with the 6 1/8-inch casing in PZ-111-KS in a telescoping arrangement. The 10-inch casing was installed to a depth of about 98 feet to isolate fine alluvial sands, while the 6 1/8-inch casing was installed to a depth of about 215 feet to isolate formations above the Warsaw Formation.

Several drilling methods were used to install the steel surface casing. Bentonite mud rotary drilling was used to stabilize significant thicknesses of saturated alluvium prior to advancing the borehole into the underlying bedrock units. A Failing KC54 mud rotary drill rig was used in conjunction with a 14 3/4-inch diameter tricone bit for installing the 10-inch steel casing. Either a 9 7/8-inch diameter tricone bit or a 10-inch diameter air percussion button bit was used for installation of the 6-inch steel casing. Neat cement grout was tremied to the bottom of the annulus between the borehole wall and the steel casing to seal the borehole. The cement grout was, at a minimum, allowed to cure overnight prior to advancing the borehole below the casing.

3.2.1.3 Leachate Riser Drilling and Sampling

Drilling methodology for solid waste borings in the inactive landfill areas was similar to the subsurface drilling methods described in Section 3.2.1.1. Drilling was conducted with 4.25-inch ID hollow stem augers. Samples of the solid waste were typically collected with a California Barrel sampler. The borehole logs designated as LR-100 through LR-105 are presented in Appendix A. The boreholes were advanced until either a potential confining layer or the base of the landfill was encountered. At the completion of drilling, the depth to fluid was measured within the hollow stem augers and recorded on the borehole logs.

During drilling, air monitoring was performed to identify explosive conditions and potential breathing hazardous to site personnel. A MiniRae photoionization detector (PID) was used to monitor volatile organic vapors. A Bacharach Sentinel 44 was used to monitor explosive vapors, hydrogen sulfide, and oxygen. Monitoring procedures and action levels specified in the Site Health and Safety Plan were followed.

3.2.1.4 Borehole Geophysical Logging

Geophysical logging of selected boreholes was performed to correlate and verify rock core logging. Geophysical logging also allows estimation of aquifer properties such as porosity and permeability.

Geophysical logging was performed in the four piezometer borehole clusters which penetrated the Keokuk Formation (boreholes PZ-100-KS, PZ-104-SD, PZ-104-KS, PZ-106-SD, PZ-106-KS, PZ-111-SD, PZ-111-KS and MW-1201). Borehole MW-1201 was logged prior to installation of piezometer casing and sealing of the borehole (renamed PZ-1201-SS). Wooddell Logging, Inc. (Wooddell) of Matoon, Illinois, was subcontracted by Golder to perform borehole geophysical logging. Each borehole, with the exceptions described below, was logged using natural gamma ray, caliper, point resistivity, gamma-

gamma (bulk density), neutron, and spontaneous potential (SP) tools. Wooddell prepared a report describing their logging tools, methods, and basic interpretation of data (Appendix B). The geophysical logs are also provided in Appendix B.

At PZ-100-KS, the borehole was logged using the natural gamma ray tool, caliper, resistivity tool, and gamma-gamma tool. In addition, a drift survey tool was used at this location to determine the actual borehole alignment. At MW-1201, only the caliper and natural gamma ray tools were used.

At three of the four clusters (i.e., PZ-104, PZ-106 and PZ-111), geophysical logging was conducted in the "SD" boreholes from ground surface to the top of the Warsaw Formation and at the "KS" boreholes from the top of the Warsaw Formation to total depth. Logging was performed in two boreholes at these locations because 6-inch steel casing had been installed to the top of the Warsaw Formation in the "KS" boreholes, preventing the subsequent use of geophysical logging equipment.

A brief description of each geophysical logging tool is provided below; detailed descriptions are contained in Wooddell's report.

- Natural Gamma Ray tool:
  - Measures natural radiation of formation continuously.
  - Shales, clays and clayey materials contain the greatest concentrations of radioactive isotopes.
  - Primarily used to distinguish clay and shale units from other materials, bed definition, determination of interfaces, and correlation.

- Caliper tool:
  - Measures the actual borehole diameter.

- Resistivity tool:
  - Indication of the water quality by measuring the apparent resistivity of the materials surrounding the borehole.

  - Provides a detailed picture of the character and thickness of various strata in the borehole.

- Gamma-Gamma tool:
  - Determination of formation density.
  - Indication of porosity. Generally, as the density increases, the porosity decreases.

- Neutron tool:
  - Indication of total porosity under saturated conditions.
  - Measures amount of hydrogen ions in the formation which generally indicates the amount of water present.

- Spontaneous Potential tool:
  - Measures natural occurring electrical potentials (voltages) that result from chemical and physical changes at the contacts between different subsurface materials.
  - Used to establish a shale or clay baseline as generally more permeable strata will have little or no shale and/or clay.

3.2.1.5 Borehole Packer Tests

Aquifer testing was performed in selected open boreholes by conductivity packer tests. The packer test results were used to determine the hydraulic conductivity in the test zones of the Keokuk, Warsaw, Salem, and St. Louis Formations. Constant head injection packer tests were performed in the four Keokuk Formation boreholes (PZ-100-KS, PZ-104-KS, PZ-106-KS, and PZ-111-KS) and three deep adjacent Salem Formation boreholes (PZ-104-SD, PZ-106-SD, and PZ-111-SD) prior to construction of piezometers. The packer test activities were supervised and performed by qualified Golder personnel.

Hydrologic packer testing was performed using a downhole packer assembly with associated surface equipment. Both double (straddle) and single packer systems were used for testing within the boreholes. Information such as the test number, depth, geologic formation, single or double packer test, and other pertinent test data is included in Appendix C-1.

Packer test zones were selected using the rock core and geophysical log information collected during advancement of the corehole and subsequent corehole reaming. The test intervals were selected by isolating zones which appeared to be:

- Relatively fractured;
- Relatively unfractured;
- Relatively porous; or,
- Relatively non-porous.

In this manner, a range of hydraulic conductivity values was obtained for each of the units.

Single packer tests were applied using a single pneumatic packer set at the top of the test interval and the bottom of the borehole as the lower point of test confinement. Double packer tests were performed using pneumatic straddle packers set around the selected test zones within the borehole. Double packer tests generally tested 5-foot intervals of borehole.

The single and double packer assemblies, consisting of one or two sliding-end pneumatic packer(s) connected to a perforated pipe, were used in conjunction with surface control equipment to perform the hydrologic packer testing. The surface assembly consisted of a variable rate water pump for controlling water injection, a flow meter manifold, a pressure gauge, valving, and hoses. Drill rods were used to lower the packer assembly into the borehole and provide a conduit for water injection. The downhole packer assembly was raised and lowered within the borehole using an air drill rig owned and operated by Layne-Western.

Flow rates into the test interval were stepped up incrementally and held steady for approximately 10 minutes to allow the pressure within the test zone to stabilize. Estimates of hydraulic conductivity were calculated using a constant head analysis method. To apply the constant head test method, the test interval was pressurized by injecting water, while the flow response, and the pressure response (head) in the test interval were monitored. The field testing procedure that was employed is summarized as follows:

- Measure tool assembly and drill rod lengths;
- Measure the depth to water below the ground surface;
- Lower packer assembly to the prescribed depth;
- Measure drill rod stick-up to ensure that the packer(s) is at the correct depth;
- Fill test system with fresh (potable) water;
- Inflate packers with downhole valve open and surface flow valves closed (minimum 150 psi to 350 psi for 6.0-inch diameter hole);
- Open surface flow valves on flow meter manifold to pressurize test interval with water;
- Check system for leakage and bleed air out of system, if necessary;
- Monitor flow rate and interval pressure until both are nearly constant;
- Perform multiple pressure steps and flow rate increases (typically three up and one down); and,
- Deflate packers and stop test.

Several steps (flow rate increases) were usually applied to the test zone to allow estimation of hydraulic conductivity at different pressures (heads) and respective flow rates. However, multiple steps were not always completed because some test zones required very high pressures to induce flow, or exhibited acceptable, minimum flow at very low pressures. In general, water was injected until a constant flow rate was established, and stabilized pressures (or head) within the test intervals could be predicted. Under these conditions, a steady state flow analysis method is applicable (Logan, 1964), and:

$$K = \frac{Q}{2\pi LH} \bullet ln(R / rw)$$

Where:

K = Average hydraulic conductivity of the test interval (L/T);
Q = Steady state flow rate (L^3/T);
L = Test interval length (L);
H = Constant head differential (constant head above static) imposed on the interval (L);
R = Radius of the pressure boundary (L); and,
rw = Radius of the corehole (L).

3.2.1.6 Geotechnical Laboratory Soil and Bedrock Testing

Geotechnical laboratory soil testing was performed at the Golder soils laboratory in Denver, Colorado on representative samples to supplement field observations and to further characterize the site soils. Samples were tested in accordance with standard ASTM methods. Laboratory tests performed included:

- Grain size;
- Natural moisture content;
- Liquid and plastic limits; and,
- Permeability testing of both undisturbed and remolded samples.

The laboratory data sheets are presented in Appendix D.

Thirteen laboratory permeability tests were performed to determine the vertical permeability of both undisturbed soil and bedrock samples, as well as remolded soil samples. Of the 13 tests, nine were performed on relatively undisturbed, field preserved Shelby tube soil samples. Two additional permeability tests were performed on recompacted, remolded soil samples. Finally, two tests were performed to determine the vertical permeability of two samples collected from near the top of the Warsaw Formation.

The remolded soil samples were designated as PS-1 and PS-2. Sample PS-1 was collected from a loess deposit in the active borrow area south of the site, and sample PS-2 was collected in the field northeast of the active sanitary landfill, in an area to be used for run-on surface water control. The remolded soil samples were tested at approximately 95 percent compaction at the optimum moisture content. The samples were consolidated with a confining pressure of 5 psi and were allowed to saturate prior to testing.

In addition to the soil testing conducted at the Golder laboratory, two siltstone core samples (GTS-1 and GTS-2) were sent to Advanced Terra Testing of Lakewood, Colorado for vertical permeability testing. These samples were collected from near the top of the Warsaw Formation in PZ-106-KS. Laboratory test results for these samples are also included in Appendix D.

3.2.2 Monitoring Point Installations

3.2.2.1 Piezometer Installation

Piezometers were installed in each of the 49 boreholes drilled by Layne-Western, under supervision of qualified Golder personnel who were state-certified monitoring well installation contractors. Piezometers were constructed according to Missouri Department of Natural Resources (MDNR) Well Construction Rules for monitoring wells (MDNR, 1993). All downhole equipment was decontaminated prior to piezometer installation, and the piezometers were constructed using either factory-cleaned and wrapped materials, or site-decontaminated materials. In either case, all downhole equipment and materials were handled by personnel wearing clean (new) disposable latex gloves. Decontamination water was disposed of in the leachate retention pond.

Typical piezometer construction details are depicted in Figure 3-2. Piezometers were constructed with 2-inch diameter, nominal 10-feet long (typical) flush threaded Schedule 80 polyvinyl chloride (PVC) casing. Each casing joint was fitted with O-rings to prevent leakage. The riser pipes extend to approximately 1.5 feet above ground surface. Vented PVC slip caps were placed over the top of the risers. Screened intervals generally consisted of nominal 10-feet long Schedule 80 PVC screens with 0.010-inch machine cut slots. A flush threaded endcap, approximately 4 inches long, was attached to the base of each screened interval as a sump to collect any sediments migrating into the piezometer and to prevent blockage of the screened interval.

Piezometers completed in alluvium were generally constructed within the hollow stem augers as the augers were retracted from the borehole. Bedrock piezometers were constructed within the open boreholes after reaming core-drilled sections with a 5 7/8-inch diameter air percussion button bit. Stainless steel centralizers were used in piezometers constructed in bedrock. The centralizers were placed at approximately 40-foot intervals to maintain the riser in the center of the borehole, consistent with Missouri Well Construction Rules published at 10 CSR 23-4.060(7) (MDNR, 1993).

After lowering the PVC screen and riser pipe into the borehole, a primary filter pack, consisting of 16/35 mesh environmental grade silica sand, was placed into the annular space of the borehole. 16/35 sand is sand with a gradation of 90 percent passing the number 16 US Standard Sieve size and 90 percent retained by the number 35 US Standard Sieve size. The primary filter pack generally extended at least 2 feet above the top of the screened interval. During primary filter placement in the piezometers constructed in the alluvium, hollow stem augers were slowly withdrawn to prevent collapse of the borehole. For both the bedrock and alluvium piezometers, the rate of sand flow into the borehole was restricted to allow for settlement and reduce the potential for bridging.

In piezometers constructed with the primary filter pack within the saturated zone, a secondary filter pack was placed over the primary filter pack to minimize the potential for the bentonite seal or grout to penetrate the primary filter pack. The secondary filter pack consists of a 0.5- to 2.0-foot thick layer of less than 50 mesh environmental grade silica sand. A tremie pipe was used to place the filter packs below the water table.

Following placement of the primary and/or secondary filter packs, a bentonite seal was placed in the borehole annulus to seal the screened interval from overlying geologic materials. The seal consists of either bentonite chips or a bentonite slurry placed with a side discharge tremie pipe. A 100 percent bentonite slurry was used if the seal zone was below the water table. Hydrated bentonite chips were used if the seal was placed above the water level in the borehole.

Surface completion consisted of installing an 8-inch square, 5-foot long steel protective casing over the PVC riser. The protective cover was placed into approximately 3 feet of concrete to reduce the potential for infiltration of surface water and to provide a firm foundation for the protective casing. The annular space between the protective cover and the riser pipe was filled with bentonite chips to ground surface, above which 1/4-inch pea gravel was placed to within 6 inches of the top of the riser. A weep hole was drilled at the base of each protective cover to provide an outlet for any water which may be introduced inside the protective cover.

A concrete pad was constructed around the protective cover and sloped away from the cover to promote drainage. In general, the aboveground portion of the pad was 3 feet by 3 feet square and a minimum of 2 feet deep around the borehole. Metal bumper posts (3 inches in diameter by 6 feet long) were placed around each piezometer located in a high traffic area. The protective covers were labeled with the appropriate piezometer designation and fitted with keyed-alike locks.

Four piezometers along the eastern boundary of the landfill (PZ-200-SS, PZ-201-SS, PZ-202-SS, and PZ-203-SS) were intended to be constructed with long screened intervals, from about 10 feet below ground surface to total depth (Golder, 1995a). The Work Plan was modified to also construct PZ-204-SS as a long screened interval piezometer. These piezometers were designed to be used for both water level and landfill gas monitoring. However, anomalously high water level readings were obtained in PZ-201-SS subsequent to installation, suggesting the potential for a perched water zone. Two additional piezometers, PZ-201A-SS and PZ-204A-SS, were drilled and constructed with a nominal 10-foot long screened interval, placed at the same depth as the bottom of PZ-201-SS and PZ-204-SS, respectively. PZ-203-SS, which had not been drilled when the anomalously high water level readings were observed in PZ-201-SS, was constructed with the nominal 10-foot long screened interval. PZ-200-SS and PZ-202-SS were constructed with the long screened interval specified in the Work Plan.

PZ-102-SS exhibited bentonite in purge water during development, indicating suspect integrity. PZ-102R-SS was drilled and constructed adjacent to PZ-102-SS as a replacement piezometer.

Piezometer completion details were recorded on piezometer construction summaries, which are provided in Appendix E-1. MDNR Division of Geology and Land Survey Monitoring Well Certification Records were completed by Layne-Western, and are supplied in Appendix F.

3.2.2.2 Piezometer Decommissioning

Alluvial piezometers PZ-300-AS and PZ-300-AD, bedrock piezometer PZ-300-SS, previously existing bedrock piezometers MW-1205 and MW-1206, and previously existing alluvial piezometers I-50 and S-80 were decommissioned in April 1996. PZ-300-AS, PZ-300-AD, PZ-300-SS, I-50 and S-80 were decommissioned due to impending property development. Verbal authorization to decommission these piezometers was obtained from EPA prior to decommissioning. Monitoring wells MW-1205 and MW-1206 were part of the active landfill's groundwater monitoring system and were decommissioned to accommodate filling sequences. The State of Missouri provided authorization to decommission monitoring wells MW-1205 and MW-1206. The piezometers and wells were decommissioned in accordance with State of Missouri procedures, which include drilling out the well materials and backfilling the hole with low permeability materials. The surface casing that had been installed through the alluvium in PZ-300-SS to isolate the bedrock monitoring zone was left in place and filled with low permeability grout. A variance was granted by the State of Missouri allowing this casing to remain in place.

3.2.2.3 Existing Monitoring Well Modification

One existing monitoring well, MW-1201, had been originally completed as an open-borehole monitoring well. As part of this investigation, MW-1201 was modified to the MDNR specifications for monitoring wells, similar to the newly-installed piezometers. The monitoring well was backfilled with a bentonite grout in the bottom of the borehole, and a neat cement plug overlying the bentonite grout (consistent with Missouri Well Construction Rules). The bentonite grout/cement grout plug was extended from the MW-1201 original completion depth of 250 feet to a depth of 148.5 feet. The borehole was then completed as a piezometer in accordance with the procedures described in Section 3.2.2. The new depth is consistent with other piezometers completed in the St. Louis and the upper portion of the

Salem Formations. Accordingly, the new piezometer has been designated PZ-1201-SS. The construction summary for PZ-1201-SS is included in Appendix E-1.

3.2.2.4 Leachate Riser Installation

Leachate risers were installed in five of the six boreholes drilled for this purpose. The leachate risers were constructed similar to the piezometers described in Section 3.2.2.1. A riser was not installed in the LR-101 borehole because neither leachate nor groundwater were encountered. Leachate riser construction summaries are provided in Appendix E-2.

3.2.2.5 Staff Gauge Installation

Two staff gauges were installed per the Work Plan in the Earth City Industrial Park stormwater retention pond southwest of the leachate retention pond. The five-foot staff gauges, which are graduated in 0.1 foot increments, were bolted to steel posts. The five-foot mark on each gauge was surveyed. Staff gauges were monitored monthly coincident with water level measurements.

3.2.3 Surveying

Monitoring point locations and elevations were surveyed by Sherbut-Carson and Associates, P.C. of Collinsville, Illinois. Northing and easting coordinates were determined to the nearest 0.1 foot, and related to the North American Datum (NAD) 1983. Top of PVC riser and ground surface elevations were determined to the nearest 0.01 foot. The ground surface elevations were rounded to 0.1 foot. Elevations were related to mean sea level (MSL). All survey data were also related to the site coordinate system. Survey elevation data are included in borehole logs, rock core logs, piezometer construction summaries, and Table 3-3.

3.2.4 Piezometer Development

The completed piezometers were initially developed by Layne-Western, with Golder supervision, using both surge block, bailing, and airlift techniques. The drill crew surged the piezometers with a stainless steel surge block for about one hour, followed by about two hours of a combination of bailing and air lifting. Airlifting was performed using an air compressor fitted with a filter to remove moisture and lubrication oil. A J-tube was used to discharge the compressed air inside 3/4-inch, threaded PVC pipe which lifted the development water to the surface. All downhole equipment was decontaminated prior to development activities at each piezometer; decontamination water was disposed of in the leachate retention pond.

The second stage of development was performed by Golder personnel. The piezometers were developed using bailers. New polyethylene rope was used at each piezometer. The bailers were decontaminated between piezometers using Liquinox™, tap water rinse, and final deionized water rinse. Golder personnel wore new disposable latex gloves when developing each piezometer.

Piezometers were developed sufficiently to remove sediments, thereby providing confident slug testing and water level elevation results. Piezometer development data is summarized in Appendix G. The development water was contained during development and was disposed of in the leachate retention pond.

3.2.5 Piezometer Slug Tests

The newly installed piezometers were slug tested to evaluate the in-situ hydraulic conductivity of the different geologic formations present at the site. An initial water level measurement was taken prior to starting the test. An instantaneous rise or fall in water level was created by rapidly inserting or extracting a stainless steel rod (slug) into the water column. If the water level was above the screen interval, the rod was rapidly inserted into the piezometer to increase the water level. In piezometers where the screened interval intersected the water column, bailing was used to induce a water level change and provide for a rising head test. Changes in the water level were monitored with a pressure transducer/data logger or manually with an electronic water level indicator.

The water level recovery was monitored until the water level in the piezometer recovered a minimum of 70 percent of its initial (static) level. If the piezometer recovered to at least 90 percent of its static level within 30 minutes, the rod was quickly removed and the rising water level was monitored until 70 percent recovery was achieved. Slug test data and results are provided in Appendix C-2.

3.2.6 Water Level, Precipitation, and River Stage Monitoring

3.2.6.1 Groundwater and Leachate Level Monitoring

A groundwater level survey was initiated in June 1995 and continued through September 1996 in order to evaluate the water level elevations in each of the geologic formations at the site and to identify the gradient and direction of groundwater flow within these formations. The water level survey consisted of measuring water levels in existing groundwater monitoring wells and in the new piezometers installed as part of this investigation.

The water level survey was conducted by measuring water levels in selected points using an electronic water level indicator. The water level probe was decontaminated between each monitoring point with Liquinox™ and a double rinse of deionized water. Field personnel wore latex gloves when handling the water level probe. Water levels were measured from a consistent marked reference point, the north rim of the monitoring point riser pipe. Data were recorded on Water Level Data forms (Appendix H-1).

3.2.6.2 Surface Water Level Monitoring

Surface water levels measured concurrent with groundwater elevations were initiated in June 1995 to identify surface water flow direction. The monthly survey was conducted by visually measuring the surface water elevation along an incremented staff gauge. Data were recorded on Water Level Data forms (Appendix H-1).

3.2.6.3 Precipitation Monitoring

A precipitation gauge capable of measuring precipitation events greater than 0.01 inch was installed at the site. Precipitation data were combined with regional data from the nearby Lambert/St. Louis International Airport, and were used to correlate fluctuations in groundwater levels with precipitation events. Precipitation data from the site and airport monitoring stations are provided in Appendix H-2.

Approximately daily readings were recorded on site from June 1 to November 14, 1995, concurrent with the installation of piezometers during the physical characterization. Regional precipitation data from the nearby Lambert/St. Louis International Airport (approximately three miles east of the site) were obtained for the same time period. The site and airport monthly precipitation totals are summarized below.

	Total Precipitation (inches)	
	Site Gauge	**Lambert Airport**
June 1995	2.41	2.96
July 1995	1.77	2.16
August 1995	5.06	4.52
September 1995	0.26	0.74
October 1995	2.51	2.01
November 1-14, 1995	0.87	1.28
TOTAL	**12.88**	**13.67**

As indicated above, precipitation totals between Lambert Airport data and site gauge data correlate very well. Based on the good correlation, daily Lambert precipitation data were used after November 14, 1995.

3.2.6.4 Missouri River Daily Stream Flow Monitoring

Daily stream flow data from the Missouri River at St. Charles were obtained from the US Geological Survey and are correlated with observed fluctuations in selected piezometers. Section 4.3.3 provides a discussion of the data.

3.2.7 Geologic Mapping

Detailed geologic mapping was conducted along the walls of the limestone quarry to evaluate stratigraphy, geologic structure, and groundwater discharge. Of the bedrock formations encountered in boreholes at the site, only the St. Louis Formation was exposed in the quarry. Other, deeper formations (i.e., the Salem and Warsaw Formations) are obscured. The stratigraphy of the St. Louis Formation was divided into five major sub-units, and geologic structures were mapped to allow comparison of large-scale geologic features to the geology obtained from the boreholes. The quarry faces afforded observation of meso-scale exposures to supplement the extensive data obtained from the rock core. A second objective of the mapping was to observe groundwater flow (seepage) from the quarry walls to better understand the groundwater flow patterns in the St. Louis Formation.

Golder geologists conducted the mapping. Horizontal distances were established by taping and pacing along the quarry faces. Approximate vertical distances were established by hand compass survey. During mapping, field maps were drawn at a working scale of 1 inch equal to 10 feet. Only exposed bedrock was mapped, surficial loess deposits overlying the

St. Louis Formation were not mapped since they were not relevant to the objectives of the mapping.

The stratigraphy of the St. Louis Formation exposed in the quarry was divided into five sub-units based on physical, mineralogical, and faunal distinctions. Physical distinctions include degree of weathering, structure (bedded, massive, brecciated, laminated, stylolitic, etc.), crystal size, and rock strength. Mineralogical distinctions include degree of argillization (clay content) and degree of silicification (chert, as nodules and stringers). Faunal distinction focused primarily on the degree of fossiliferous material present. However, faunal types (brachiopods, gastropods, crinoids, etc.) are indicated in the lithologic descriptions. Geologic structures mapped included joints, collapsed infilled structures, and cavities.

4.0 FINDINGS OF INVESTIGATION

4.1 Geology

4.1.1 Bedrock

Bedrock formations of hydrologic importance underlying the West Lake site are sedimentary members of the Paleozoic Mississippian and Pennsylvanian systems. The Mississippian System formations present include the Osagean and Meramecian Series (Thompson, 1986). The bedrock formations of interest beneath the site, listed in order of oldest to youngest, consist of the Keokuk Formation (upper portion of the Osagean Series), the Warsaw Formation (lower portion of the Meramecian Series), the Salem Formation (middle portion of the Meramecian Series), the St. Louis Formation (middle portion of the Meramecian Series) and the Cheltenham Formation (lower portion of the Pennsylvanian System). The upper portion of the Meramecian Series (St. Genevieve Formation) is not present at the site. Each of these formations is described individually below. Geologic cross sections at the locations shown in Figure 4-1 were developed. The cross sections depict vertical and horizontal distribution of these units in Figures 4-2 through 4-5.

4.1.1.1 Keokuk Formation

The Keokuk Formation at the site was generally identified as a fresh to slightly or moderately weathered, thin- to medium-bedded, very light gray to light olive, medium- to coarse-grained, medium strong, fossiliferous limestone. Similar dolomite and dolomitic limestone beds were also present in the Keokuk Formation, and chert layers and nodules were observed. The members of the Keokuk Formation were variously described as siliceous and arenaceous as well as porous and vuggy. Fractures were infrequent (generally less than two fractures per foot) and generally described as irregular and rough. Some fractures were bedded and planar. In general, open vugs and/or porous zones were identified below or at about elevation 100 ft (MSL) at the four boreholes that penetrated the Keokuk Formation. The geophysical logs generally confirmed the visual classifications and descriptions of the Record of Drillhole logs prepared by Golder personnel.

The Keokuk Formation was encountered approximately 365 to 375 feet below ground surface along the eastern edge of the active sanitary landfill, at elevations ranging from about 115 to 126 feet MSL. Along the western edge of the active sanitary landfill, the Keokuk Formation was encountered approximately 345 feet below ground surface at an elevation of about 115 feet MSL. The structural surface of the Keokuk Formation is depicted in Figure 4-6.

The site descriptions of the Keokuk Formation compare favorably with regional descriptions. Thompson (1986) and Howe (1961) describe the unit as a mostly medium-crystalline limestone, with some finely to coarsely crystalline and/or crinoidal zones. Chert, which is common throughout the formation, is more abundant in the lower and upper parts. The chert is light gray and nodular, often with tripolitic (disintegrated chert) borders. In eastern Missouri, the Keokuk Formation is represented by conodont fauna and is nearly indistinguishable from that of the limestones in the overlying Warsaw Formation.

4.1.1.2 Warsaw Formation

The Warsaw Formation at the site was generally described as fresh and thickly bedded, with numerous beds of calcareous claystone and fossiliferous limestone. Many interbeds of dolomite, claystone, siltstone, clayey siltstone, and silty claystone were also observed. The lower portion of the Warsaw Formation is predominantly limestone, and grades into the upper portion of the Keokuk Formation. The upper portion of the Warsaw was characterized by a 2.5 to 10.0 feet thick claystone or siltstone layer, commonly referred to as the Warsaw Shale. The color ranged from dark greenish gray to olive black, and the beds were very fine- to very coarse-grained or micro- to coarsely-crystalline. The rock strength varied from weak to medium strong. Thin beds of the formation were characterized by vuggy porosity. Various portions were described as arenaceous (sand) or argillaceous (clay). The lower portion of the formation was thin- to medium-bedded, and included thin chert layers and small chert nodules.

In general, the geophysical logs confirmed the visual classifications and descriptions of the Record of Drillhole logs prepared by Golder personnel. The top of the Warsaw Formation can be easily identified on the geophysical logs (Appendix B).

Fractures in the Warsaw Formation were rare, and generally did not exceed a frequency of one fracture per foot. Observed fractures were generally jointed, irregular or planar, and rough or smooth. Clay infilling of joints was common. An example of a natural fracture is depicted in Photograph 1 in Figure 4-7. Photograph 1 also depicts the infrequent fracturing in the Warsaw Formation. Photograph 1 is also provided in Appendix A as Figure A-4.

Geotechnical laboratory testing of the two Warsaw Formation samples collected from borehole PZ-106-KS obtained vertical permeability values of 1.5 x 10^{-10} cm/sec and less than 1.1 x 10^{-10} cm/sec, and porosity values of 13.81 and 14.73 percent.

The Warsaw Formation was encountered at about 245 feet below ground surface (approximately 240 feet MSL elevation) near the eastern edge of the active sanitary landfill. Along the western active sanitary landfill edge, the Warsaw Formation was encountered at depths ranging from about 200 to 210 feet below ground surface, equivalent to about 250 to 260 feet MSL elevation. These elevations roughly correspond to the base of the old quarry pit (Midwest Environmental, 1994), indicating that quarrying terminated at the top of the Warsaw Formation. The unit thickness ranged from about 130 to 145 feet. The structural surface of the Warsaw Formation is depicted in Figure 4-8.

Regional descriptions of the Warsaw Formation identify the argillaceous (clay) content of this unit as characteristic of the upper portion (Thompson, 1986 and Howe, 1961). The argillaceous content was apparently derived from sources to the east, in the Illinois basin. The lower portions of the formation are described as principally composed of finely to coarsely crystalline, fossiliferous limestone.

4.1.1.3 Salem Formation

The Salem Formation at the site was generally identified as a fresh, thinly- to thickly-bedded, medium strong limestone. The color of the formation was typically described as pale yellowish brown to light olive gray. The limestone was variously described as argillaceous or arenaceous, bioclastic, fossiliferous, or fossiliferous dolomitic limestone. Interbedded dolomite layers were common, and chert clasts, nodules, and layers were scattered throughout the formation at varying frequencies. In general, the geophysical logs confirmed the visual classifications and descriptions of the Record of Drillhole logs prepared by Golder personnel.

Fractures were rare in the Salem Formation. The lower portion of the formation generally exhibited zero to one fracture per foot. The upper portion of the formation generally exhibited up to two fractures per foot. The fractures were characterized as jointed, irregular, and rough; or, as jointed, planar, and smooth.

The Salem Formation was encountered at a depth of about 165 feet along the eastern edge of the active sanitary landfill (about 320 feet MSL elevation). Depth to the formation along the western active sanitary landfill edge ranged between 115 and 135 feet, with the formation surface elevation between 328 and 340 feet MSL elevation. The thickness of the Salem Formation ranged between 67 and 83 feet. The structural surface of the Salem Formation is depicted in Figure 4-9.

Regional descriptions of the Salem Formation emphasize the dolomitic and fossiliferous nature of the limestone (Thompson, 1986 and Howe, 1961). Regionally, the top of the formation grades conformably upward into the St. Louis formation, and the intermediate beds contain coral, foraminifera, and echinoderm fossils and fragments. The upper 50 feet of the Salem in the St. Louis area contains a high percentage of speckled gray and tan chert. As noted above, the Salem Formation beneath the site included chert nodules and layers throughout its thickness.

4.1.1.4 St. Louis Formation

Core Descriptions

The St. Louis Formation was generally described from core samples as interbedded fresh to slightly weathered limestone and dolomite. The unit grades into the underlying Salem Formation. Bedding ranged from thin to very thick, and color ranged from very light gray to olive gray. The unit was typically classified as fine to medium crystalline or fine- to medium-grained, and medium strong. The limestone beds were variously characterized as arenaceous, argillaceous, dolomitic, or clastic. Claystone and siltstone beds and layers were periodically observed. Chert was not commonly identified. In general, the geophysical logs confirmed the visual classifications and descriptions of the Record of Drillhole logs prepared by Golder personnel.

Fracturing ranged from zero to ten fractures per foot, and the fractures were generally classified as jointed, irregular, or rough. Fractures were generally infilled with clay. Stylolitic joints were also observed. Examples of drilling-induced and natural fractures are depicted in Photographs 2 and 3 in Figure 4-7; these photographs are also provided in Figure A-4 of Appendix A.

Depth to the St. Louis Formation ranges from about 14 to 52 feet below ground surface along the eastern edge of the active sanitary landfill, and between 20 and 110 feet below ground surface along the western edge of the active sanitary landfill. The top of the St. Louis Formation ranges between about 425 and 460 feet MSL elevation in the eastern portion of the site, and between 379 and 442 feet MSL elevation in the western portion of the site. This variation reflects the buried edge of the Missouri River valley and the limestone bluffs upon which the quarry was sited. The thickness of the St. Louis Formation ranges from about 65 to 130 feet. The structural surface of the St. Louis Formation is depicted in Figure 4-10. The approximate location of the edge of the alluvial valley is also indicated on Figure 4-10.

4.1.1.5 Cheltenham Formation

The Cheltenham Formation was only encountered near the surface at PZ-301-SS. Literature describes the formation as consisting of clays and associated clastics, lying above Ordovician-to-Mississippian-aged strata and below Pennsylvanian-aged strata. The clays are mostly white to light - or medium - gray to purplish or red (Thompson, 1995). Thin coal beds are also present in the formation.

At PZ-301-SS, the Cheltenham Formation was identified from 19.1 to 71.5 feet below grade. The surrounding area had previously been excavated and lies within the landfill borrow area. The formation was generally described from core samples as predominantly olive to greenish gray to light brownish gray claystone. Thin limestone, siltstone, and coal beds were identified. With the exception of the upper 10 feet of the formation, the core was relatively unfractured.

Geologic Mapping

Stratigraphy

The stratigraphic position of the St. Louis Formation units, and geologic descriptions generated during geologic mapping of the quarry walls, are presented on Figures 4-11 and 4-12. During the geologic mapping, the quarry was divided into five sectors which coincide with the five prominent quarry walls. The sector locations are shown on Figure 4-13.

The St. Louis Limestone exposed in the quarry was divided into five sub-units. Progressing from oldest to youngest sub-unit, these have been designated for this mapping task as Lb, Ls, Ld, Bx and Lx. These units are described below:

> **Lb** - This is the basal unit currently exposed at the site. The Lb unit is a thinly bedded, microcrystalline to finely crystalline thinly to thickly bedded LIMESTONE.
>
> **Ls** - This unit currently overlies the Lb unit. The Ls unit is a massive, microcrystalline, medium strong, very argillaceous LIMESTONE. This unit displays a sheet-like weathering pattern such that thin (0.2 to 0.4 feet thick) slabs separate from the rock mass parallel to the exposed face. Localized joints, fractures, and seeps were not noted within this unit.
>
> **Ld** - This unit overlies the Ls unit. The Ld unit is relatively thin (1.0 to 3.0 feet thick) and is almost continuously exposed in the quarry. The unit is a thinly bedded to massive, medium strong to strong, slightly argillaceous LIMESTONE. A finely laminated, approximately 2-inch thick layer of fine-grained material is present at the upper contact of this unit. The persistence and predominantly horizontal nature of this unit make it an excellent stratigraphic marker bed. A marker bed provides a point of reference relative to the stratigraphy.
>
> **Bx** - The Bx unit overlies the Ld unit. The Bx unit is a massive, brecciated, finely crystalline (matrix), medium strong, LIMESTONE. The Bx unit ranges from about 10 to 22 feet thick.

Lx - The Lx unit overlies the Bx unit. This is the uppermost unit exposed in the quarry. The Lx unit is thinly to thickly bedded, fine to medium crystalline, coarsening upward, medium strong, stylolitic, fossiliferous (brachipods, gastropods, crinoids), LIMESTONE with some iron-oxide concretions, some argillaceous stringers and some chert nodules. Surficial loess overlies the Lx unit.

Geologic Structure

Three types of geologic features were mapped in the quarry. These are joints, cavities and infilled collapsed features. The orientations of the joints mapped are shown on Figure 4-13. Groundwater seeps on the quarry faces were also mapped.

The joints that were mapped may be divided into two primary sets. One set has a population of four joints, all oriented at 020 degrees east of north. The second set has a population of about 20 joints. Orientations for this set range from 055 to 098, with a mean orientation of 066 degrees east of north. The western portion of Sector 4 and the majority of Sector 5 exhibit the densest population of mapped joints. Sector 1, which is sub-parallel to the joint set, did not exhibit a significant number of 058 to 080 degree joint sets. However, the face has an excavated strike orientation of 060 degrees. Thus, the joints of this predominant joint set may have been removed during excavation of the quarry.

Infilled collapsed features are voids in the bedrock which have been infilled with fine-grained sediments. None of these features were observed in Sector 1, four of these features were observed in Sector 2, and two of these features were observed in Sector 3. Five of these features were observed in Sector 4, and three of these features were observed in Sector 5. Several of the smaller infilled collapsed features have a basal termination at the Bx/Ld contact. The larger features have generally propagated into the Ls unit.

Seeps

Eighty-eight seeps were observed on the quarry faces. Similar to the infilled collapsed features, many of these seeps occur above the Ls unit at the Bx/Ld contact and within the Ld unit. The presence of seeps above the Ls contact suggests that the Ls unit is less transmissive than overlying units.

4.1.2 Unconsolidated Materials

Overview

Unconsolidated materials at the site consist primarily of alluvium and loess. The surficial loess at the site was redeposited during the late Pleistocene. Silt was picked up from braided glacial melt-out drainages by westerly winds. The thickness of these loessial deposits is greatest in the eastern regions of the drainages and diminishes rapidly to the west. Thus, the bluffs and hills immediately east of the site are composed of loess in deposits up to 80 feet thick, but the loess deposits directly adjacent to the quarry at the site are relatively thin (Thompson, 1986). Loess was identified as silty clay and clayey silt in deposits from 13 to 22 feet thick along the eastern edge of the active sanitary landfill. Underlying alluvial deposits, when present, ranged from silty clay and clayey silt to sand, and ranged from about 12 to 32 feet thick.

Loess was not commonly encountered along the western edge of the active sanitary landfill. Where encountered, loess deposits in the western portion of the site were about 10 to 15 feet thick, and occasionally interbedded with alluvial deposits. The alluvial deposits along the western edge of the site ranged in thickness up to about 120 feet. The thickness of the alluvial deposits and the depth to top of bedrock increased to the west, indicating the presence of the previously-mentioned alluvial valley. Alluvial deposits typically consisted of fine-grained (clay and silt) materials overlying coarse-grained (sand and gravel) materials. The silt and clay are derived from periodic flooding of the Missouri River (overbank deposits). The coarse-grained materials are point bar deposits, and were identified as predominantly poorly-sorted sands. The thickness of the unconsolidated materials, and the edge of the alluvial valley, is depicted in Figure 4-14.

Laboratory Test Results

Geotechnical laboratory test results of unconsolidated materials are summarized in Table 4-1. Laboratory testing was performed to estimate natural moisture content values for 19 soil samples. The value of natural moisture content ranged from 14.0 to 37.4 percent.

Specific gravity values were obtained for 28 samples. Values for specific gravity range from 2.51 to 2.81, with a mean value of 2.69. Specific gravity is a unit-less value. The specific gravity values were used in conjunction with the hydrometer tests to determine the particle size distribution of the materials finer than the 200 mesh sieve. Particle size distribution curves are provided in Appendix D.

Thirty-two samples were submitted for Atterberg Limit tests. However, nine of the samples were determined to be non-plastic and were classified as ML (silt), SP (poorly graded sand), or SM (sandy silt) according to the USCS. The liquid limits of the 23 remaining samples ranged from 31 to 80 percent. The plasticity index ranged from 8 to 29 percent. These results indicate a predominance of clay in the samples. Fourteen of the samples were classified as CL (clay), one was classified as CH (clay), one was classified as ML (silt), and two were classified as CL-ML (clayey silt).

Laboratory flexible wall permeability tests were also performed on selected samples (Table 4-2). Permeability for soil samples was found to range between 2×10^{-7} centimeters per second (cm/sec) and 2×10^{-4} cm/sec. These results are discussed further in Section 4.2.3.

4.1.3 Solid Waste

Solid waste was identified at four of the six leachate riser borehole locations. Solid waste was not present at LR-103 or LR-104. The location of the leachate riser boreholes are shown on Figure 3-1 and the borehole logs are presented in Appendix A. At LR-100, LR-101, and LR-105, the full section of solid waste was penetrated and the base of solid waste was identified. At LR-102, the borehole did not extend to the base of solid waste because an apparent confining layer was identified within the solid waste. A silty layer was identified from 58.0 to 62.8 feet and separated more recent solid waste from older solid waste. The solid waste in LR-102 was saturated at a depth of 53.0 feet from the top of the landfill cap, and the silty layer also appeared to be saturated. The older solid wastes encountered below 62.8 feet were not saturated. The borehole was advanced to 76.0 feet, and the base of the borehole immediately sealed with hydrated bentonite chips below 61.6 feet to seal off the unsaturated solid wastes encountered below 62.8 feet.

In general, the solid waste consisted of common municipal wastes such as paper, plastics, clothing, construction and demolition debris. At LR-102, the older solid waste consisted of predominantly wood, construction debris, and other materials that were charred from burning.

Monitorable quantities of leachate were identified during drilling at LR-100, LR-102, and LR-105. Piezometers consisting of 2-inch ID Schedule 80 PVC were installed at these locations. At LR-101, monitorable quantities of leachate were not identified during drilling. At this borehole, old mine spoils consisting of very fine sand and laminated lime deposits were encountered at 55 feet below the landfill cap. Water was encountered in the old mine spoils. The old mine spoils were separated from the overlying solid wastes by about 3 feet of silt. Since monitorable quantities of leachate were not identified within the solid waste at LR-101, the borehole was immediately sealed with cement/bentonite grout to the surface.

At LR-103 and LR-104, solid wastes were not encountered; however, piezometers were installed in the boreholes to monitor groundwater levels in the alluvial deposits.

4.2 Site Hydrogeology

4.2.1 Introduction

Hydrogeologic characterization of a site requires an understanding of the hydrogeologic system controlling groundwater flow.

The scope of the hydrogeologic study portion of the physical characterization focused on both the saturated and unsaturated units of the St. Louis and Salem Formations, the Warsaw Formation, and the upper unit of the Keokuk Formation, and their interaction with local hydrogeologic controls. Pertinent hydrogeologic controls include formational boundaries, the quarry, and other potential recharge and discharge sources (seeps, leachate collection system, precipitation, and the Missouri River).

The following sections present the hydrogeologic parameters and controls for groundwater flow at the site. The geologic setting at the site was discussed in Section 4.1.

4.2.2 Water Level Elevations

Piezometers have been installed at the West Lake Site to monitor groundwater within the Keokuk Formation, the lower portion of the Salem Formation, and the upper portion of the Salem Formation, the St. Louis Formation, and the Missouri River floodplain alluvial deposits. Water level elevations measured in piezometers during June 1995 to July 1996 are provided in Table 4-3. The potentiometric surface of each of these units is discussed in the following paragraphs, followed by a discussion of groundwater gradient in the hydrogeologically significant units. The following summary is based on the June 1995 through July 1996 water level data. The majority of 100- and 200-series piezometers were installed and developed by June of 1995. The 300-series piezometers were installed and developed by October 1995. To provide complete concurrent data sets, potentiometric surface maps from October 1995, January 1996, April 1996, May 1996, and July 1996 are presented and discussed. October 1995, January 1996, April 1996, and July 1996 represent data for fall, winter, spring, and summer, respectively. May 1996 data are included because they provide additional relevant data.

As previously described, the leachate recovery system in the active landfill consists of four sumps installed at the bottom of the quarry (at an elevation of approximately 240 feet MSL). In accordance with the terms of the sanitary landfill permit, the regulated leachate head is generally maintained at or below 30 feet, corresponding to an elevation of about 270 feet MSL. Leachate pumping from the active landfill exerts hydrogeologic control on a large portion of the site by creating a hydraulic sink. Groundwater from all sides of the active landfill flows towards the risers. A groundwater divide has apparently been created in the alluvium on the western portion of the site. Groundwater east of the divide flows towards the risers. Groundwater west of the divide flows generally west/northwest, consistent with regional flow directions.

4.2.2.1 Potentiometric Surface

Keokuk Formation

Water level elevations in the Keokuk Formation at the site range from about 439 feet MSL at PZ-111-KS to about 444 feet MSL at PZ-104-KS. These water levels are indicative of confined, artesian groundwater conditions, since the elevation of the structural surface of the Keokuk Formation is about 120 feet MSL (Figure 4-6). Water level elevations measured in October 1995, January 1996, April 1996, and July 1996 in the KS-series piezometers were used for development of the Keokuk Formation potentiometric surface maps (Figures 4-15, 4-16, 4-17, and 4-18). The interpreted water level elevation potential in the Keokuk Formation underlying the active sanitary landfill is approximately 200 feet above the base of the active landfill and 170 feet above the regulated leachate level in the active landfill. Based on the Keokuk Formation water level elevations and the regulated leachate levels, groundwater from the Keokuk Formation has the potential to flow upwards toward the active sanitary landfill, acting as a hydraulic barrier to potential downward flow of leachate.

Warsaw Formation

Significant groundwater was not encountered in the Warsaw Formation. Accordingly (consistent with the EPA-approved RI/FS Work Plan [Golder, 1995a]), piezometers were not completed within this unit, and a potentiometric surface map was not developed.

Deep Salem Formation

Four piezometers were completed in the deep portion of the Salem Formation (PZ-100-SD, PZ-104-SD, PZ-106-SD, and PZ-111-SD). Water level elevations measured in October 1995, January 1996, April 1996, May 1996, and July 1996, in the SD-series piezometers were used for development of the deep Salem hydrologic unit potentiometric surface maps (Figures 4-19, 4-20, 4-21, 4-22, and 4-23). Water levels measured in these piezometers range between 340 and 440 feet MSL, which is 100 to 200 feet above the elevation of the base of the active landfill and 70 to 170 feet above the regulated maximum leachate level. Groundwater flow in the deep Salem Formation near the active landfill is toward the landfill. It is likely that groundwater in the Salem Formation resumes its regional northwesterly flow direction some distance west of the landfill, outside the cone of depression created by the limestone quarry excavation and the active landfill's leachate collection system.

As shown on Figure 4-22, leachate levels in LCS-1, LCS-3, and LCS-4 were abnormally high on May 3, 1996. The relatively high leachate levels were the result of temporary malfunctions of the pumps in these risers that occurred in late April. The pump malfunctions coincide with approximately 5 inches of precipitation that fell between April 28 and April 30. The temporary lack of pumping in LCS-1, LCS-3, and LCS-4 allowed the leachate level in the risers to reach equilibrium with the surrounding leachate in the landfill. The temporary pump malfunctions were beneficial to the hydrogeologic characterization by confirming that the inward hydraulic gradient was maintained even during periods of significantly reduced leachate pumping, combined with excessive precipitation.

St. Louis/Upper Salem Formations

The St. Louis Formation and the upper portion of the Salem Formation, while geologically distinct, are considered a single hydrologic unit at the site. The "SS" piezometers installed as part of the recent investigation were typically completed within the St. Louis Formation but, based on geologic conditions encountered during drilling, some of the "SS" piezometers were completed in the upper portion of the Salem Formation (i.e., PZ-106-SS, PZ-108-SS, PZ-109-SS, and PZ-113-SS). The depth of the screened intervals and the lack of a significant hydraulic flow barrier between the two formations (as indicated by the gradational contact discussed in Section 4.1.1.4) indicate that the formations are hydraulically connected. The formations are collectively referred to as the St. Louis/Upper Salem hydrologic unit.

Water level elevations in the St. Louis/Upper Salem hydrologic unit range from about 333 feet MSL at PZ-116-SS to about 444 feet MSL near PZ-202-SS. Water level elevations measured in October 1995, January 1996, April 1996, and July 1996, in the SS-series piezometers were used as monitoring points for construction of the St. Louis/Upper Salem hydrologic unit potentiometric surface maps (Figures 4-24, 4-25, 4-26, 4-27, and 4-28) at the site. Groundwater flow near the active landfill is towards the landfill. It is likely that groundwater in the St. Louis and Upper Salem Formations resumes its regional northwesterly flow direction some distance west of the landfill, outside the cone of depression created by the limestone quarry excavation and the active landfill's leachate collection system.

The May and July 1996 data for the St. Louis/Upper Salem unit (Figures 4-27 and 4-28) confirm the inward hydraulic gradient east of the landfill. Piezometer PZ-203-SS, which generally remained dry (water level <374.5 feet MSL), exhibited measurable water levels of 377.56 and 375.52 feet MSL during May and July 1996, respectively. These water levels are about 100 feet above the leachate sump elevations during leachate pumping and about 70 feet above the leachate elevation in the active landfill when leachate is not being pumped.

Unconsolidated Materials

Groundwater is present within the unconsolidated materials in both perched and unconfined conditions. Perched groundwater is present at the contact between the loess and the uppermost bedrock (St. Louis Formation) along the eastern portion of the active sanitary landfill. No piezometers were installed to monitor the perched groundwater at the loess/limestone contact because groundwater at this contact is discontinuous and very thin (i.e., generally less than 2 feet thick).

Piezometers installed in unconsolidated materials (alluvium) as part of the recent investigation are situated in a north-south oriented line along the western edge of the active sanitary landfill, and southern and western edges of the inactive landfill. Data obtained from these piezometers were combined with data from existing monitoring wells to develop water table maps for unconsolidated materials. Unconsolidated materials water table maps based on these data are provided in Figures 4-29, 4-30, 4-31, 4-32 and 4-33.

Groundwater flow within the alluvial unconsolidated materials adjacent to the active landfill is toward the landfill. An alluvial groundwater divide apparently exists west of the active landfill, as would be expected based on regional data. East of the divide, alluvial groundwater flow is towards the active landfill. West of the divide, alluvial groundwater flow is west/northwest towards the Missouri River.

4.2.2.2 Gradient

Horizontal Gradient

Horizontal hydraulic gradients have been calculated for the Keokuk Formation and the St. Louis/Upper Salem hydrologic unit using the potentiometric contours shown in Figures 4-15 through 4-18 and 4-24 through 4-28, respectively. Gradients were calculated by dividing the difference in head between two contours by the distance between the two contours (dH/dL). The range of values was determined by interpreting these measurements at the minimum and maximum sloping areas of the potentiometric surface map.

The horizontal hydraulic gradient for groundwater flow in the Keokuk Formation was calculated to range from approximately 0.0039 feet/foot (ft/ft) to 0.0082 ft/ft. Groundwater flow within the Keokuk Formation is predominantly to the west and northwest toward the Missouri River (Figures 4-15 through 4-18). However, because the top of the Keokuk Formation is about 200 feet below the base of the Missouri River and is separated by approximately 60 feet of the confining Warsaw Formation, the Keokuk Formation and the Missouri River are not expected to be hydraulically connected.

The deep Salem groundwater flow is towards the active landfill, as shown on Figures 4-19 to 4-23. The deep Salem piezometers confirm the inward hydraulic gradient to the landfill. Deep Salem piezometers were not installed to determine horizontal gradients.

The horizontal hydraulic gradient for the St. Louis/Upper Salem hydrologic unit was found to range from approximately 0.037 ft/ft to 0.008 ft/ft north of the north pit to approximately 0.45 ft/ft to 1.0 ft/ft along the west and south wall of the south pit. As depicted in Figures 4-24 through 4-28, the gradient and direction of groundwater flow in the St. Louis/Upper Salem hydrologic unit indicate that the active sanitary landfill functions as a groundwater sink. Groundwater in the vicinity of the active sanitary landfill flows toward the landfill, with gradient increasing near the active sanitary landfill. The hydraulic head in the St. Louis/Upper Salem hydrologic unit is generally about 65 to 175 feet above the leachate riser level in the active sanitary landfill.

Alluvial water levels show generally flat gradients that range below 0.0001 ft/ft. The alluvial water level in piezometers near the active landfill is about 80 to 150 feet above the leachate riser level in the landfill.

Vertical Gradient

Vertical hydraulic gradients were calculated using water level elevations measured in the piezometers at each of the four bedrock piezometer clusters. The vertical hydraulic gradient is calculated by taking the differential hydraulic heads (dH) in two piezometers and dividing by the vertical distance (dL) between the screen center points of the two piezometers. The vertical hydraulic gradient is calculated to establish the vertical gradient magnitude and direction, and is a parameter used to calculate vertical groundwater velocities. Tables 4-4 through 4-8 provide a summary of the vertical hydraulic gradients calculated using water level elevations from the piezometer pairs taken on October 28, 1995, January 4, 1996, April 3, 1996, May 3, 1996, and July 12, 1996.

The bedrock vertical gradients range from -0.05 ft/ft to -0.62 ft/ft (upward) for the KS-series/SD-series piezometers and 0.03 ft/ft to 0.38 ft/ft (downward) for the

SD-series/SS-series piezometers. The vertical gradient is upward from the Keokuk Formation to the Salem Formation (KS-series/SD-series). The generally strong upward gradient from the Keokuk Formation through the Warsaw Shale to the Salem Formation indicates that groundwater has the potential to flow upward from the Keokuk Formation toward the base of the active landfill. In each case, the gradient is downward from the St. Louis Formation to the Salem Formation (SS-series/SD-series).

Vertical hydraulic gradients have also been calculated for piezometer clusters which include alluvium and bedrock piezometers. These gradient values are also provided in Tables 4-4 through 4-8. The vertical hydraulic gradients for the shallow alluvium to intermediate or deep alluvium and for the deep alluvium to shallow bedrock at certain piezometer clusters are generally negligible, ranging from very slightly downward to very slightly upward.

4.2.3 Hydraulic Conductivity

In-situ packer and slug tests, and laboratory permeability tests, were performed as part of the recent investigation. Packer testing was performed using a constant head test method, slug tests were performed using primarily a rising head method, and laboratory testing was performed using a triaxial permeability test method. Packer tests were performed on both saturated and unsaturated bedrock units, while slug tests and laboratory permeability tests were performed only on saturated units.

Packer Tests

The constant head test method was successfully applied to test intervals in selected open coreholes (i.e., PZ-100-KS, PZ-104-SD, PZ-104-KS, PZ-106-SD, PZ-106-KS, PZ-111-SD and PZ-111-KS). The double packer test interval lengths were set at five feet, while the single packer test intervals ranged from 10 feet to 148 feet. Analysis was conducted on data collected from tests performed on both saturated and unsaturated intervals. Results from tests performed in the unsaturated intervals have been reported as intrinsic permeability (i.e., permeability to air), while tests performed in the saturated intervals have been reported as hydraulic conductivity. The results are presented in these units since intrinsic permeability is a function of the flow medium while hydraulic conductivity is a function of both the flow medium and fluid (i.e., water). Tests were performed in the unsaturated intervals to allow for landfill operator to separately calculate landfill gas migration, while tests in the saturated intervals were performed to augment groundwater flow calculations. Parameters used to estimate the intrinsic permeability and hydraulic conductivity tests are provided in Appendix C. A summary of the packer testing results is included as Tables 4-9 (Keokuk Formation), 4-10 (Warsaw Formation), 4-11 (Salem Formation), and 4-12 (St. Louis Formation).

Keokuk Formation

The constant head test analysis for tests completed in the Keokuk Formation (Table 4-9) resulted in hydraulic conductivity values ranging from 7.6×10^{-7} cm/sec to about 4.3×10^{-5} cm/sec for the tested intervals. The geometric mean hydraulic conductivity was calculated to be 9.7×10^{-6} cm/sec. Although the Keokuk Formation tests resulted in the highest geometric mean hydraulic conductivity of the three formation units, this mean hydraulic conductivity value is low.

Warsaw Formation

The constant head test analysis for the Warsaw Formation tests (Table 4-10) resulted in hydraulic conductivity values ranging from 2.6×10^{-7} cm/sec to about 5.6×10^{-5} cm/sec for the tested intervals. The geometric mean hydraulic conductivity for the Warsaw Formation tests was calculated to be 2.6×10^{-6} cm/sec. Some packer tests conducted in the Warsaw Formation included the upper portion of the Keokuk Formation. Warsaw Formation hydraulic conductivity values for these tests were calculated by subtracting the Keokuk

Formation contribution to the hydraulic conductivity value from the entire test interval, using the following equation (from Todd, 1980):

$$Kxt = \frac{(K_1 Z_1 + K_2 Z_2)}{Z_1 + Z_2}$$

Where:

Kxt = Hydraulic conductivity for entire test interval
K_1 = Hydraulic conductivity of Warsaw Formation portion of test interval (unknown)
K_2 = Hydraulic conductivity of Keokuk Formation portion of test interval
Z_1 = Length of Warsaw Formation portion of test interval
Z_2 = Length of Keokuk Formation portion of test interval

Salem Formation

The constant head test analysis for the Salem Formation (Table 4-11) resulted in hydraulic conductivity values ranging from about 5.8×10^{-8} cm/sec to about 2.5×10^{-5} cm/sec, with a calculated geometric mean of 1.6×10^{-6} cm/sec.

St. Louis Formation

The constant head test analysis for the saturated interval tests in the St. Louis Formation (Table 4-12) resulted in hydraulic conductivity values ranging from 3.7×10^{-7} cm/sec to 4.4×10^{-6} cm/sec. The geometric mean hydraulic conductivity value for the saturated interval of the St. Louis Formation is 9.6×10^{-7} cm/sec.

The constant head test analysis for the St. Louis Formation unsaturated interval tests resulted in intrinsic permeability values ranging from 1.5×10^{-12} centimeters squared (cm^2) to about 7.5×10^{-9} cm^2 for the tested intervals. The highest intrinsic permeability value was measured near the loess/bedrock contact at PZ-100-KS. Other than the highest value measured at PZ-100-KS, these values are low and indicate that the bedrock will restrict the migration of landfill gas. The geometric mean intrinsic permeability of the unsaturated interval was calculated to be 4.9 x 10^{-11} cm^2.

Slug Tests

Hydraulic conductivity values have been calculated using data obtained from slug tests performed in piezometers completed in the Keokuk Formation, the deep portion of the Salem Formation, the St. Louis/Upper Salem hydrologic unit, and the alluvium. The calculated hydraulic conductivity values from slug tests estimated for each of the piezometers tested are summarized in Table 4-13. Hydraulic conductivity values shown on this table were calculated using the methods developed by Hvorslev (1951), Bouwer and Rice (1976), and Cooper-Papadopulos (1967). Where slug tests were conducted in piezometers prior to static water levels being reached, and when falling head slug tests were conducted within the sand pack, results of the tests are shown on the tables but have not been included in geometric means used for subsequent calculations; nor are results of these tests included in the permeability ranges presented below.

For the Keokuk Formation, the calculated Cooper-Papadopulos hydraulic conductivity ranges from 6.0 x 10^{-7} cm/sec to 3.8 x 10^{-6} cm/sec, with a geometric mean value of 2.1 x 10^{-6} cm/sec. This value is within the range of the geometric mean hydraulic conductivity values calculated from the packer test analysis.

The hydraulic conductivity values for the slug-tested piezometers completed in the deep portion of the Salem Formation ranged between 1.0 x 10^{-7} cm/sec and 1.8 x 10^{-5} cm/sec for the Hvorslev analysis, and between 6.8 x 10^{-8} cm/sec and 1.2 x 10^{-5} cm/sec for the Bouwer and Rice analyses. The geometric mean hydraulic conductivity values were 8.4 x 10^{-7}

(Hvorslev) and 5.4 x 10^{-7} (Bouwer and Rice), with a combined geometric mean value of 6.9 x 10^{-7} cm/sec.

The hydraulic conductivity values from slug tests in the piezometers completed in the St. Louis/Upper Salem hydrologic unit ranged from about 1.7 x 10^{-8} cm/sec to 3.0 x 10^{-3} cm/sec, with a calculated Hvorslev geometric mean of 3.0 x 10^{-6} cm/sec and a calculated Bouwer and Rice geometric mean of 1.2 x 10^{-6} cm/sec. The mean of both methods was calculated to be 1.1 x 10^{-6} cm/sec. These values confirm the packer test hydraulic conductivity values.

The geometric mean of hydraulic conductivity values for the tests conducted in the deep alluvial piezometers were 6.7 x 10^{-4} cm/sec for the Hvorslev analysis and 5.0 x 10^{-4} cm/sec for the Bouwer and Rice analysis. The geometric mean hydraulic conductivity value for the combined tests was calculated to be 5.9 x 10^{-4} cm/sec.

The geometric mean of hydraulic conductivity values for the test conducted in the intermediate alluvial piezometers were 1.8 x 10^{-2} cm/sec for the Hvorslev analysis and 1.2 x 10^{-2} cm/sec for the Bouwer and Rice analysis. The geometric mean hydraulic conductivity for the combined tests was calculated to be 1.5 x 10^{-2} cm/sec.

For shallow alluvial piezometers, the calculated Hvorslev geometric mean hydraulic conductivity is 2.5 x 10^{-3} cm/sec and the calculated Bouwer and Rice geometric mean hydraulic conductivity is 3.9 x 10^{-3} cm/sec. Bouwer and Rice analyses were not performed for several of the slug tests in this group where Bouwer and Rice analyses were inappropriate. The mean value of both tests is 2.9 x 10^{-3} cm/sec.

Laboratory Permeability Tests

The mean from the two Warsaw Formation rock core samples submitted for vertical permeability analysis was estimated to be 1.3×10^{-10} cm/sec (Table 4-2). This value is very low and is indicative of a very good confining unit and aquitard for groundwater within the Keokuk Formation.

Laboratory testing of unconsolidated materials identified the permeability of the undisturbed samples collected from near surface soils and loess deposits as ranging from 3×10^{-4} cm/sec to 3×10^{-7} cm/sec, and a geometric mean of 2.2×10^{-6} cm/sec. The values for the two remolded samples ranged from 2×10^{-7} cm/sec to 3×10^{-7} cm/sec, suggesting relatively low hydraulic conductivity for the unconsolidated materials.

Summary

Field and laboratory tests were performed to determine hydraulic conductivity of the hydrologic units investigated at the site. Field aquifer tests included packer and slug tests, while laboratory tests consisted of flexible wall permeability tests. Geometric means of each test were calculated, as well as the geometric mean for the combined tests. The horizontal hydraulic conductivity test results are summarized below.

Formation	Packer Test Geometric Mean	Slug Test Geometric Mean	Permeability Test Geometric Mean	Combined Test Geometric Mean
Keokuk	9.7×10^{-6}	2.1×10^{-6}	not tested	4.5×10^{-6}
Warsaw	2.6×10^{-6}	not tested	not tested	2.6×10^{-6}
Salem	1.6×10^{-6}	6.9×10^{-7}	not tested	1.1×10^{-6}
St. Louis	9.6×10^{-7}	1.3×10^{-6}	not tested	1.1×10^{-6}
Unconsolidated Materials	not tested	2.9×10^{-3}	2.2×10^{-6}	1.0×10^{-4}

Note: All values provided in centimeters per second (cm/sec).

The slug test results generally confirm packer test results, and the combined results demonstrate the similarities between the tested units. It should be noted that the horizontal hydraulic conductivity of the Warsaw Shale was not measured as part of the aquifer test procedures. Vertical hydraulic conductivity testing of the Warsaw Shale portion of the Warsaw Formation was conducted as part of the laboratory permeability tests. As previously discussed, vertical permeability of the Warsaw Shale was found to average 1.3×10^{-10} cm/sec, indicating that the Warsaw Shale acts as an aquitard between the underlying Keokuk Formation and the overlying Salem Formation.

4.2.4 Groundwater Velocities and Flow Rates

As discussed in Section 4.2.2, hydraulic head data collected from piezometers screened in the Keokuk Formation, St. Louis/Upper Salem hydrologic unit, and unconsolidated materials indicate that horizontal groundwater flow in the Keokuk Formation is towards the west and northwest, while groundwater flow in the St. Louis/Upper Salem hydrologic unit is toward the active landfill. Horizontal groundwater flow in the alluvium near the active landfill is toward the landfill. In the western portion of the site, alluvial groundwater flow is generally to the west and northwest, consistent with regional groundwater flow direction.

Typical groundwater velocities for flow within the bedrock were calculated using the horizontal gradient and hydraulic conductivity values discussed in Sections 4.2.2 and 4.2.3 (respectively), effective porosity values of 10 and 20 percent, and assuming steady-state conditions. Similarly, groundwater velocity was calculated for unconsolidated materials using appropriate gradient and hydraulic conductivity values, an effective porosity value of 30 percent, and assuming steady-state conditions. These porosity values are within the range presented by Freeze and Cherry (1979) for limestone, dolomite, and alluvium, and, for the bedrock units, are within the range of the two Warsaw Formation sample porosity values obtained by laboratory testing (i.e., 13.81 percent and 14.73 percent). These values should be representative of the range of effective porosity values of the hydrologic units at the site. The groundwater velocities were calculated using the following equation:

$$V = \frac{Ki}{n_e}$$

Where:

V = Average linear velocity (feet/year)
K = Hydraulic conductivity (cm/sec)
i = Hydraulic gradient (feet/foot)
n_e = Effective porosity

Table 4-14 shows groundwater velocities range from 0.03 feet per year (ft/yr) to 0.2 ft/yr in the Keokuk Formation and 0.3 ft/yr to 5.0 ft/yr in the St. Louis/Upper Salem hydrologic unit. Groundwater velocity in shallow unconsolidated materials was calculated to average about 0.5 ft/yr or less, due to flat gradients.

The groundwater flow volume from the Keokuk Formation through the Warsaw Shale to the active sanitary landfill (area from which leachate is pumped) can be calculated using the following equation:

$$Q = KiA$$

Where:

Q = Groundwater flow volume (gallons/day)
K = Hydraulic conductivity (cm/s)
i = Hydraulic gradient (feet/feet)
A = Approximate cross-sectional area of quarry (square feet)

Using a mean hydraulic conductivity value of 1.3 x 10^{-10} cm/sec, a hydraulic gradient of 1.43 ft/ft, and a unit area of about 35.9 acres (floor space of the active sanitary landfill), the groundwater flow volume theoretically entering the pit from the Warsaw Formation was calculated to be 6.2 gallons per day (gal/day). This value indicates that the volume of water entering the quarry from the lower formations is insignificant.

A vertical groundwater velocity for the Warsaw Shale has been calculated using the equation presented above. Laboratory permeability tests indicate that the mean vertical hydraulic conductivity of two Warsaw Shale core samples was 1.3×10^{-10} cm/sec. The vertical hydraulic gradient from the Keokuk Formation to the floor of the pit was calculated using the differential hydraulic head divided by the differential distance I= (442 ft - 270 ft)/(240 ft - 120 ft) = 1.43 ft/ft. The average bulk porosity was calculated to be 14.3 percent. Therefore, assuming the effective porosity to be equivalent to the bulk porosity, and using parameters presented above, the vertical groundwater velocity upward through the Warsaw Formation is estimated to be about 1.4×10^{-3} ft/yr, or 3.7×10^{-6} ft/day.

4.2.5 Seasonal Fluctuations in Groundwater Levels

Monthly groundwater level measurements in the newly-installed piezometers was initiated in June 1995 (Table 4-3). Piezometeric levels set in shallow bedrock wells near the active landfill reflect and are indicative of both leachate pumping and seasonal changes.

In general, water levels do not vary significantly from month to month or season to season. Water levels typically vary by ± one foot or so.

A significant rainfall event (2.57 inches) occurred December 18 and 19, 1995. Water levels in selected piezometers were monitored over the following 16 days. Graphs of piezometer response to the precipitation event are presented in Appendix H-2. Monitoring yielded the following data:

- Alluvial piezometers (PZ-113-AS, PZ-113-AD, PZ-300-AS, PZ-300-AD) show little response. It is likely that the relatively high permeability of approximately 3 x 10^{-3} cm/sec in the alluvium (see Section 4.2.3) allows rapid dissipation of recharge and prevents mounding.

- In the St. Louis/Upper Salem piezometers PZ-104-SS, PZ-106-SS and PZ-113-SS, response occurred within one to five days of the event. In St. Louis/Upper Salem piezometers PZ-100-SS, PZ-110-SS and PZ-300-SS, little response was noted. Piezometer PZ-301-SS was not at equilibrium at the time of monitoring.
- In deep Salem piezometers PZ-100-SD, PZ-104-SD and PZ-106-SD registered relatively rapid responses (one day). PZ-111-SD showed little response to the event.
- In the Keokuk piezometers monitored (PZ-100-KS, PZ-104-KS, PZ-106-KS and PZ-111-KS), response to the rainfall event was slight, as expected given the presence of an overlying aquitard.

Based on the data, precipitation does not significantly affect alluvial water levels or the Keokuk potentiometric surface. Recharge does appear to affect the St. Louis potentiometric surface and the deep Salem potentiometric surface.

4.2.6 Seasonal Gradients

Groundwater level data were used to identify variations of the seasonal gradients and direction of flow. Horizontal gradients are controlled by pumping from the landfill, so are generally unaffected by gross seasonal changes. Vertical gradients do not show significant seasonal fluctuations.

4.3 Hydrology

4.3.1 Precipitation and River Stage

Precipitation data from the period of 1961 through 1990 was obtained from *The Weather Almanac* (Gale, 1992). Missouri River stage data from the period of 1984 through 1994 were obtained from the Water Resources Division of the US Geological Survey. The average annual precipitation, as reported at the St. Louis/Lambert International Airport, is 37.02 inches per year. Precipitation and river stage data are summarized in Tables 4-15 and 4-16, respectively. Figure 4-34 depicts the relationship between river stage and precipitation, based on monthly averages from the referenced time periods. While basin-wide precipitation generally correlates with river stages in typical drainage systems, local precipitation at the site may not directly correlate with Missouri River stage, as evidenced by November precipitation that trends opposite to November river stage (Figure 4-34).

4.3.2 Surface Drainage Patterns

Surface drainage at the site is indicated in Figure 4-35. In general, surface water from the eastern portion of the site flows towards the site surface water retention pond. Based on a 36-acre landfill footprint, 37-inches of precipitation per year, conservatively assuming no evaporation, and recognizing that no runoff can occur from the below-grade active landfill, precipitation falling into the active sanitary landfill is estimated to contribute an average about 99,000 gallons per day to the approximately 216,000 gallons per day of leachate pumped. Precipitation falling in the active sanitary landfill is recovered by the leachate collection system and discharged to the leachate retention pond. Surface runoff in the western portion of the site generally flows towards the Earth City industrial park stormwater retention pond, or westward in a drainage ditch along St. Charles Rock Road. Stormwater dikes are present around the landfill to prevent run-on from neighboring properties.

4.3.3 Hydrologic Relationship Between the Site and the Missouri River

Daily stream flow data from the Missouri River at St. Charles were obtained from the US Geological Survey (USGS), and is correlated with observed fluctuations in piezometer well clusters PZ-100-SS/SD/KS and PZ-113-AS/AD/SS. Piezometer water levels near the active landfill are controlled by leachate pumping and any influence by river stage would be difficult to detect. The piezometers selected are of sufficient distance from the south pit to be least affected by the active landfill's inward hydraulic gradient.

Of the six piezometers selected, one is completed in shallow alluvial materials; one in deep alluvial materials; two within the Salem/Upper St. Louis hydrologic unit; one within the Deep Salem hydrologic unit; and, one within the Keokuk Formation.

As shown in Appendix H-2, there is not a direct correlation between Missouri River stage data and fluctuations in groundwater levels at the site. This lack of correlation is consistent with other hydrogeologic data, such as distance from the site to the riser (2 miles).

Historical stream flow data were also correlated with historical precipitation data. Stream flow data are provided in Appendix H-3. As expected, stream flow generally increases in response to precipitation.

5.0 SUMMARY

5.1 Physical Characterization Summary

The OU-2 physical characterization included the following activities:

- Drilling 56 boreholes, which included collecting nearly 3,300 feet of rock core and 1,500 feet of unconsolidated material samples. Over 6,000 feet of drilling was performed;
- Geophysical logging of selected boreholes;
- Packer testing of 49 intervals in the various bedrock formations;
- Construction of piezometers in 50 boreholes, and modification of one existing monitoring well;
- Installation of six leachate riser boreholes;
- Developing and slug testing each piezometer constructed as part of this investigation;
- Laboratory testing of soil and rock samples;
- Monitoring water levels in the piezometer and leachate risers; and,
- Detailed geologic mapping of quarry walls.

The investigation was performed in accordance with the requirements outlined in the EPA-approved OU-2 Work Plan.

The extensive characterization activities have allowed for development of a detailed hydrogeologic summary and hydrogeologic model, as described below.

5.2 Geologic Summary

The site is located at a transition zone between the alluvial floodplain and loessial bluffs. The eastern portion of the site consists of loess overlying bedrock. The western portion of the site consists of alluvium overlying bedrock. A layer of unconsolidated materials, ranging in thickness from about 25 feet on the east side of the active sanitary landfill to about 120 feet on the west side of the site, overlies limestone bedrock. The unconsolidated materials predominantly consist of silt and silty clay (loess) on the east side, and silty, fine to coarse sand (alluvium) on the west side.

The uppermost bedrock at the site is the St. Louis Formation, a 65- to 130-foot thick limestone and dolomitic limestone unit. The St. Louis Formation conformably grades into the underlying Salem Formation, which is a similar limestone and dolomite unit. The Salem Formation is differentiated from the St. Louis Formation by fossils and chert. Underlying the Salem Formation is the Warsaw Formation, which includes about 30 to 50 feet of claystone or siltstone. The Warsaw Formation is commonly known as the Warsaw Shale, and forms the base of the active landfill. The Warsaw Formation overlies the Keokuk Formation, which is generally described as a coarse crystalline fossiliferous limestone. These formations are of the Paleozoic Era, Mississippian System, Upper Osagean and Meramecian Series.

The recent investigation characterized the above formations in a subsurface drilling program, in accordance with the EPA-approved Remedial Investigation/Feasibility Study Work Plan, Operable Unit 2, West Lake Landfill, Bridgeton, Missouri (Golder, 1995a). A literature review identified deeper formations as older Mississippian limestone units with some shale and siltstone, and Devonian, Silurian, and Ordovician limestone, shale, and sandstone deposits. Underlying Cambrian units are cherty dolomite, siltstone, sandstone, and shale, and Precambrian rocks are igneous and metamorphic.

5.3 Hydrogeologic Summary

Groundwater is present in alluvial materials west of the active sanitary landfill and in the bedrock of the Keokuk, Warsaw, Salem, and St. Louis Formations adjacent to and beneath the site. The alluvial materials are present in the western portion of the site. The St. Louis Formation and the upper portion of the Salem Formation are hydraulically connected; this unit has been identified as the St. Louis/Upper Salem hydrogeologic unit. The upper and lower portions of the Salem Formation are also hydraulically connected; the differentiation is an artificial designation used for convenience, based on the completion depths of the newly-installed piezometers.

Groundwater elevations and flow directions in all units remain consistent seasonally. In addition, water levels at the site appear unaffected by Missouri River stage.

The Keokuk Formation, the deepest unit studied at the site, is separated from the Salem Formation by the Warsaw Formation, which includes about 30 to 50 feet of claystone and siltstone and is referred to locally as the Warsaw Shale. Groundwater is present in the Keokuk Formation under confined conditions; the Warsaw Shale, with a vertical hydraulic conductivity of approximately 1×10^{-10} cm/sec, acts as an aquitard confining the Keokuk Formation. Horizontal groundwater flow in the Keokuk Formation is predominantly towards the east and northeast. Vertical flow from the Keokuk Formation is potentially upward, thereby acting as a hydraulic barrier to downward migration of leachate from the active landfill.

Groundwater in the deep Salem hydrologic unit flows inward toward the active landfill and is recovered by the leachate collection system, discharged to the site leachate retention pond, and released to the St. Louis Metropolitan Sewer District.

Regionally, unconfined groundwater in the St. Louis/Upper Salem hydrologic unit flows to the west and northwest, towards the Missouri River. The active landfill's leachate collection system is required by permit to maintain a 30-foot head of leachate within the active sanitary landfill, at an elevation of about 270 feet MSL. The difference in water level elevations in the St. Louis/Upper Salem hydrologic unit as compared to leachate elevations within the active landfill leachate risers is up to about 175 feet. The leachate level within the active sanitary landfill is well below the piezometric surface of the surrounding area. Groundwater in the St. Louis/Upper Salem hydrologic unit flows inward towards the active sanitary landfill. Groundwater entering the active sanitary landfill from the St. Louis/Upper Salem hydrologic unit is recovered by the leachate collection system, discharged to the site leachate retention pond, treated, and released to the St. Louis Metropolitan Sewer District System.

Only trace quantities of groundwater were observed during drilling by Golder personnel in the loess deposits east of the active landfill. Groundwater was identified in thin saturated layers within the loess and thin sand layers within the loess or at the bedrock contact. The saturated layers were generally less than one-foot thick and did not contain significant quantities of groundwater.

The depth to groundwater within the alluvial deposits monitored in July 1996 ranged from a minimum of about 6.5 feet at MW-107 to about 30.5 feet below ground surface at PZ-207-AS. Water level data indicate that the potentiometric surface of the alluvial water table is relatively flat. Alluvial groundwater near the active landfill flows towards the landfill, similar to groundwater flow in the upper bedrock units at the site. A groundwater divide appears to exist west of the landfill. West of the divide, alluvial groundwater flow is west/northwest towards the Missouri River. Water levels within the nested monitoring wells completed in the alluvium were very similar, showing little vertical gradient and indicating that local semi-confining layers are not present.

Groundwater flow rates at the site are very slow. The Keokuk Formation flow rate is calculated to be less than 0.2 ft/yr. Flow rate in the St. Louis/Upper Salem hydrologic unit is less than 5 ft/yr. Alluvial groundwater flow rates are about 0.5 ft/yr, due to the relatively flat hydraulic gradient in the alluvium. Flow rates are higher near the active landfill in response to the inward hydraulic gradient created by leachate collection in the landfill.

5.4 Conceptual Hydrogeologic Model

The extensive physical characterization at the site allows development of a detailed hydrogeologic model (Figure 5-1). As depicted on Figure 5-1, leachate collection from the active landfill is the major hydrogeologic feature at the site. Leachate collection has maintained an inward hydraulic gradient from the adjacent deep Salem, St. Louis/Upper Salem, and alluvial hydrologic units that was developed when the limestone quarry created a local hydraulic sink by excavating below the water table. The inward hydraulic gradient prevents horizontal migration of leachate away from the landfill into the surrounding units. Vertical migration away from the active landfill is prevented by a combination of low-permeability shales that form a natural landfill liner, leachate pumping, and an upward hydraulic gradient from the underlying Keokuk Formation.

The leachate collection process has maintained a groundwater divide west of the active landfill. East of the divide, groundwater flow is towards the landfill and the leachate collection system. West of the divide, groundwater resumes its regional west/northwest flow direction.

The hydrogeologic model has been used to develop a proposed monitoring network, as described in Section 6.

6.0 PROPOSED MONITORING NETWORK

As proposed in the Work Plan and described in this Physical Characterization Technical Memorandum, information obtained during the field investigation has been used to identify the physical characteristics of the site such that a monitoring network can be confidently developed. This section describes the network proposed to monitor groundwater, surface water, sediment, and leachate quality at the West Lake Landfill OU-2. The proposed monitoring network is depicted in Figure 6-1. Twenty-four piezometers/wells are proposed to be included in the monitoring network, along with two surface water, two sediment, and eight leachate sampling points. The results of the OU-2 monitoring will be combined with monitoring results from OU-1 activities to provide a characterization of site-wide conditions. Thirty-six Operable Unit 2 locations are proposed for chemical characterization. The 36 Operable Unit 2 sampling locations are supplemented with data available from 28 wells and piezometers sampled by Operable Unit 1. In total, Operable Unit 1 and Operable Unit 2 sampling results will be available from 54 separate sampling locations spread across the entire site. The extensive, widespread sampling points are considered sufficient to yield appropriate data for characterizing site environmental conditions, for use in risk assessment determinations, and for evaluating remedial alternatives as part of the feasibility study phase of the project.

6.1 Groundwater Monitoring Analytes and Sample Locations

As discussed in Section 3.2.2.1, 49 piezometers were installed to monitor groundwater elevations in alluvial and bedrock aquifers at the site. The conceptual hydrogeologic model described in Section 5.4 shows that groundwater in the alluvial and bedrock hydrologic units near the active sanitary landfill flows toward the active landfill, while groundwater in the underlying Keokuk Formation is isolated from the overlying hydrologic units and is unaffected by site activities. Groundwater monitoring for the alluvial and upper two bedrock hydrologic units (i.e., St. Louis/Upper Salem and Salem Formations) is proposed.

Groundwater monitoring for the lower hydrologic unit (i.e., the Keokuk Formation) is not considered necessary due to its hydraulic isolation from the landfill.

The inward hydraulic gradient toward the active landfill will prevent migration of leachate away from the landfill. The inward hydraulic gradient suggests that groundwater quality monitoring near the active landfill is unnecessary. However, the monitoring network proposed below includes groundwater quality determination near the landfill to confirm the results of the physical characterization.

Twenty-one of the recently-installed piezometers, and three existing monitoring wells, are proposed to be included in the groundwater monitoring network. As previously noted, the piezometers were completed to monitoring well specifications in anticipation of potential conversion to monitoring well use. The existing monitoring wells provide historical data from the current RCRA groundwater monitoring program. The network will consist of piezometers and wells which are located in areas that fulfill specific data needs for characterization of the site.

As described in Section 3.2, piezometers installed as part of the recent investigation were completed as single piezometers or in clusters. Single piezometers were sited to characterize site-wide hydrogeologic conditions or to target specific potential hotspots. The piezometer clusters are located around the active sanitary landfill, and provide both general hydrogeologic data and vertical gradient information. Single and clustered piezometers are included in the monitoring network, and analytical results from samples collected from the clustered piezometers will allow preparation of vertical water quality profiles.

As shown on Figure 6-1, groundwater quality in the northern portion of the site is proposed to be monitored by piezometers PZ-208-SS, PZ-114-AS, and monitoring wells I-68, S-84, D-85, I-67, I-66, MW-F3, D-13, and I-65. Piezometer PZ-114-AS and monitoring wells I-68, S-84, D-85, I-67, I-66, MW-F3, D-13, and I-65 were included in Operable Unit 1 sampling. Accordingly, groundwater quality data will be available from 10 points spaced across the northern portion of the site.

Figure 6-1 illustrates 16 monitoring wells and piezometers (i.e., S-8, I-62, D-83, MW-101, I-7, D-6, S-61, I-2, S-1, D-93, I-9, S-82, MW-103, PZ-304-AS, PZ-304-AI, and PZ-303-AS) along the western boundary of the site. Twelve of the monitoring wells and piezometers were included in Operable Unit 1 sampling. These data are proposed to be supplemented with four additional groundwater sampling points as part of the Operable Unit 2 RI/FS. These data should provide excellent coverage of groundwater quality on the western boundary of the site.

An additional 19 wells and piezometers in the southern, eastern, and central portion of the site are proposed to be sampled as part of the Operable Unit 2 RI/FS.

Groundwater samples will be analyzed for the parameters listed on Tables 6-1 and 6-2, consistent with the EPA-approved RI/FS Work Plan (Golder, 1995b). The following subsections provide the rationale for including the selected piezometers and wells in the groundwater monitoring network.

6.1.1 Alluvial Monitoring Points

The alluvial groundwater is proposed to be monitored by the following seven piezometers and wells:

- PZ-303-AS
- PZ-304-AS
- PZ-304-AI
- PZ-113-AS
- PZ-113-AD

- MW-103
- MW-107

These alluvial monitoring points will provide background/upgradient alluvial water quality data, as well as water quality data for specific areas on-site. As noted in Section 5.3, hydrogeologic information from the clustered alluvial piezometers verified that the alluvium at the site acts as a single hydrogeologic unit. The rationale for including each monitoring point in the network is provided below.

- PZ-303-AS monitors water quality in the shallow portion of the alluvial aquifer west and potentially downgradient of the inactive landfill. Groundwater quality data from PZ-303-AS will detect potential impacts from the inactive landfill area on groundwater which could be flowing toward the Earth City industrial park stormwater retention pond. Additionally, PZ-303-AS is located adjacent to existing monitoring well MW-F2, where petroleum hydrocarbons have been historically identified.

- PZ-304-AS and PZ-304-AI monitor water quality in the shallow and intermediate portions of the alluvial aquifer west and potentially downgradient of the inactive landfill, and will also monitor potential impacts from the landfill area on groundwater which could be flowing toward the Earth City industrial park stormwater retention pond. These piezometers may be used to monitor vertical water quality variances within the alluvial aquifer.

- PZ-113-AS and PZ-113-AD monitor water quality in the shallow and intermediate portions of the alluvial aquifer in the area between the inactive demolition landfill and the active sanitary landfill. These piezometers may be used to monitor vertical water quality variances within the alluvial aquifer.

- MW-103 monitors water quality in the shallow portion of the alluvial aquifer west and potentially downgradient of the inactive landfill, and will also monitor potential impacts from the landfill area on groundwater which could be flowing towards the Earth City industrial park stormwater retention pond.

- MW-107 monitors water quality in the shallow portion of the alluvial aquifer in a background location approximately 2700 feet upgradient of the active sanitary landfill.

6.1.2 St. Louis / Upper Salem Monitoring Points

The piezometers completed in the St. Louis/Upper Salem aquifer provide water quality data in the uppermost bedrock unit, which directly underlies the majority of the site. Additionally, this unit is located adjacent to the active sanitary landfill. Even though available data indicate that all St. Louis/Upper Salem piezometers as upgradient of the active landfill, the following twelve piezometers are proposed to monitor the water quality in the St. Louis/Upper Salem aquifer:

- PZ-100-SS
- PZ-102R-SS
- PZ-1201-SS
- PZ-104-SS
- PZ-106-SS
- PZ-110-SS
- PZ-201A-SS
- PZ-204A-SS
- PZ-206-SS
- PZ-113-SS
- PZ-208-SS
- PZ-301-SS

Piezometers PZ-100-SS, PZ-104-SS, PZ-106-SS, PZ-110-SS, and PZ-113-SS are included in cluster locations. Combined with water quality data from other piezometers in the clusters, data obtained from PZ-100-SS, PZ-104-SS, PZ-106-SS, PZ-110-SS, and PZ-113-SS will be used to develop vertical water quality profiles.

PZ-206-SS is located adjacent to a former underground storage tank, near the center of the site. Water quality data from PZ-206-SS will be used to provide general uppermost aquifer water quality information and to identify impacts from this potential hotspot.

PZ-102R-SS, PZ-201A-SS, PZ-204A-SS, and PZ-208-SS encompass the landfill area and were selected to provide general uppermost bedrock water quality information. PZ-204A-SS is located immediately upgradient of the site and will provide background water quality data.

PZ-1201-SS is part of the routine monitoring system for the active landfill. OU-2 water quality data will supplement the existing database for PZ-1201-SS.

PZ-301-SS is located south of the site and was also selected to provide background water quality data for the uppermost bedrock aquifer.

6.1.3 Deep Salem Monitoring Points

Four piezometers and one existing site monitoring well are proposed to monitor groundwater quality in the deep portion of the Salem aquifer. The following locations are proposed to be monitored:

- PZ-100-SD
- PZ-104-SD
- PZ-106-SD
- PZ-111-SD
- MW-1204

The four piezometers are part of the clusters noted above and were completed to monitor water quality immediately above the Warsaw Formation. Existing monitoring well MW-1204 is also completed to the top of the Warsaw Formation. The base of the active sanitary landfill is located at the top of the Warsaw Formation. These piezometers and the well will monitor the water quality adjacent to the base of the landfill, and would be the first locations to detect releases from the active sanitary landfill. The piezometers will also provide information to assist in the development of vertical water quality profiles.

6.2 Surface Water Monitoring Analytes and Sample Locations

Surface water quality will be monitored in the Earth City industrial park stormwater retention pond southwest of the site. One sample (SW-01) will be collected upstream of the site, and another sample (SW-02) will be collected immediately west of the site. Surface water samples will be analyzed for the parameters listed on Table 6-1, consistent with the EPA-approved RI/FS Work Plan (Golder, 1995b).

6.3 Sediment Monitoring Analytes and Sample Locations

Impacts to sediments will be monitored at the two surface water quality sampling points in the Earth City industrial park stormwater retention pond. The two sediment samples will be collected adjacent to the surface water sample locations discussed in Section 6.2.

Sediment samples will be analyzed for the parameters listed on Table 6-3, consistent with the EPA-approved RI/FS Work Plan (Golder, 1995b).

6.4 Leachate Monitoring Analytes and Sample Locations

Leachate quality will be monitored in leachate risers completed in the inactive landfill and leachate collection sumps in the active sanitary landfill. The following leachate monitoring points are proposed:

- LR-100
- LR-103
- LR-104
- LR-105
- LCS-1
- LCS-2
- LCS-3
- LCS-4

Leachate riser LR-102 is not included in the proposed monitoring network because the leachate thickness in LR-102 has consistently been approximately six inches or less. Leachate riser LR-102 is not expected to yield sufficient leachate for sampling.

The leachate risers ("LR" prefix) are located at EPA-identified potential liquid waste disposal sites in the inactive landfill (USEPA, 1989 and USEPA, 1991). Leachate samples will be analyzed for the parameters listed on Table 6-1, consistent with the EPA-approved RI/FS Work Plan (Golder, 1995b). Analytical results of samples collected from these monitoring points will be compared to typical municipal solid waste leachate constituents to identify variances which may indicate industrial or hazardous waste disposal in the inactive landfill. The leachate collection sumps ("LCS" prefix) are located near the four corners of the active sanitary landfill. Analytical results of samples collected from these monitoring points will be used to identify impacts from other on-site sources, such as radiological constituents from OU-1.

6.5 Split-Sample Locations

The EPA-approved RI/FS Work Plan (Golder, 1995b) included a provision for EPA to collect split samples at its discretion. Subsequent to approval of the Work Plan, EPA provided approval for Operable Unit 2 to recommend split sample locations and to select a laboratory to perform analysis of the split samples. Final selection of a split laboratory has not been made. Table 6-4 lists the proposed split sample locations for groundwater, surface water, sediment, and leachate. Operable Unit 2 proposes to collect and analyze split samples at 13% of the groundwater sampling locations (three split samples for each round of 24 groundwater sampling locations), 50% of the surface water and sediment sampling locations (one split sample for two surface water and sediment sampling locations, respectively), and 25% of the leachate sampling locations (two split samples for eight leachate sampling locations). The split sample results will assist in determining the accuracy of the primary laboratory.

Groundwater split sample locations are proposed to include at least one split from each of the saturated units to be sampled (alluvium, uppermost bedrock, and deep bedrock). In addition, groundwater split sample locations were selected to provide data in areas considered critical from a risk assessment standpoint (MW-103, PZ-303-AS and PZ-304-AS, which are located between the inactive landfill and the Earth City Retention Pond; plus, PZ-208-SS located north of the site across St. Charles Rock Road), and in a background uppermost bedrock sample location (PZ-204A-SS). Surface water and sediment split sample locations are proposed to be collected immediately downgradient of the inactive landfill area. For leachate, one split sample (LR-105) is proposed to be collected from the leachate risers installed in potential industrial/hazardous waste disposal areas inferred by EPA, and another split sample is proposed to be collected from a leachate riser in the active sanitary landfill (LCS-1).

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TABLE 2-1
GENERALIZED STRATIGRAPHIC COLUMN
WEST LAKE LANDFILL

System	Series	Group	Formation	Thickness (feet)	Dominant Lithology	Water-Bearing Character
Quaternary	Holocene		Alluvium	0-150	Sand, gravel, silt, and clay.	Some wells yield more than 2,000 gpm.
	Pleistocene		Loess Glacial Till	1-110 0-55	Silt Pebbly clay and silt.	Essentially not water yielding.
Pennsylvanian	Missourian	Pleasanton	Undifferentiated	0-75	Shales, siltstones, "dirty" sandstones, coal beds and thin limestone beds.	Generally yields very small quantities of water to wells. Yields range from 0-10 gpm.
	Desmoinesian	Marmaton	Undifferentiated	0-90		
		Cherokee	Undifferentiated	0-200		
	Atokan		Cheltemham Formation	Unknown		
Mississippian	Meramecian		Ste. Genevieve Formation	0-160	Argillaceous to arenaceous limestone.	Yields small to moderate quantities of water to wells. Yields range from 5 to 50 gpm. Higher yields are reported for this interval locally.
			St. Louis Limestone	0-180		
			Salem Formation	0-180		
			Warsaw Formation	0-110	Shales in upper portion, limestone in lower portions.	
	Osagean		Burlington-Keokuk Limestone	0-240	Cherty limestone	
			Fern Glen Formation	0-105	Red limestone and shale.	
	Kinderhookian	Chouteau	Undifferentiated	0-122	Limestone, dolomitic limestone, shale and siltstone.	
Devonian	Upper	Sulphur Springs	Bushberg Sandstone	0-60	Limestone and sandstone	
			Glen Park Limestone			
			Grassy Creek Shale	0-50	Fissile, carbonaceous shale	
Silurian			Undifferentiated	0-200	Cherty Limestone	

Notes provided on Page 2.

TABLE 2-1
GENERALIZED STRATIGRAPHIC COLUMN
WEST LAKE LANDFILL

System	Series	Group	Formation	Thickness (feet)	Dominant Lithology	Water-Bearing Character
Ordovician	Cincinnation		Maquoketa Shale	0-163	Silty, calcareous or dolomitic shale.	Probably constitutes a confining influence on water movement.
			Cape Limestone	0-5	Argillaceous limestone.	Yields small to moderate quantities of water to wells. Yields range from 3 to 50 gpm. Decorah Formation probably acts as a confining bed locally.
	Champlainian		Kimmswick Formation	0-145	Massive limestone	
			Decorah Formation	0-50	Shale with interbedded limestone	
			Plattin Formation	0-240	Finely crystalline limestone	
			Rock Levee Formation	0-93	Dolomite and limestone, some shale.	
			Joachim Dolomite	0-135	Primarily argillaceous dolomite.	
			St. Peter Sandstone	0-160	Silty sandstone, cherty limestone grading upward into quartzose sandstone	Yields moderate quantities of water to wells. Yields range from 10-140 gpm.
			Everton Formation	0-130		
	Canadian		Powell Dolomite	0-150	Sandy and cherty dolomites and sandstone	Yields small to large quantities of water to wells. Yields range from 10 to 300 gpm. Upper part of aquifer group yields only small amounts of water to wells.
			Cotter Dolomite	0-320		
			Jefferson City Dolomite	0-225		
			Roubidoux Formation	0-177		
			Gasconade Dolomite Gunter Sandstone Member	0-280		
Cambrian	Upper		Eminence Dolomite	0-172	Cherty dolomites, siltstones, sandstone, and shale.	Yields moderate to large quantities [illegible] to wells.
			Potosi Dolomite	0-325		Yields range from 10 to 400 gpm.
		Elvins	Derby-Doerun Dolomite	0-165		
			Davis Formation	0-150		
Precambrian					Igneous and metamorphic rocks.	Does not yield water to wells in this area.

NOTES: Basal part of alluvium may be Pleistocene age.
Stratigraphic nomenclature may not necessarily be that of the U.S.Geological Survey.
Aquifers most favorable as water sources are shaded.
Double-line indicates unconformity.

SOURCE: *Water Resources of the St. Louis Area, Missouri. (Miller et al., 1974).*

TABLE 3-1
PREVIOUS INVESTIGATION SUMMARY
WEST LAKE LANDFILL

Year(s)	Investigation Conducted for:	Description
1973	West Lake Landfill	Four wells at unknown locations were sampled for five sampling rounds; samples were analyzed for general inorganic parameters, metals, and phenol.
1976	West Lake Quarry	Three wells along the western property boundary were sampled in one sampling round; samples were analyzed for general inorganic parameters, metals, and phenol.
1976-1984	West Lake Quarry	Wells around the perimeter of the inactive landfill on the western portion of the site, and after 1981 near the leachate retention pond, were sampled intermittently. Samples were analyzed for a varying list of parameters which included general inorganic parameters, ions, metals, and radionuclides.
1979-1982	Missouri Department of Natural Resources	Wells around the perimeter of the inactive landfill and the perimeter of the site, as well as site surface water bodies and off-site private wells, were sample intermittently. The samples were analyzed for a varying list of general inorganic parameters, ions, metals, and radionuclides.
1982	Nuclear Regulatory Commission	The *Radiological Survey of the West Lake Landfill, St. Louis County, Missouri* identified two areas of radiological contamination on-site, and concluded that there is no indication of off-site migration of the contaminants.
1983	College of Engineering, University of Missouri-Columbia	The *Engineering Evaluation of Options for Disposition of Radioactively Contaminated Residues Presently in the West Lake Landfill, St. Louis County, Missouri, Draft* identified radiological contamination and concluded that radon gas release from the site would increase.
1984	Nuclear Regulatory Commission	The perimeter berm around the northern extent of the site was surveyed for radiological contamination and inspected for erosion. Migration of contamination and slope failure were observed on selected portions of the berm west of OU-2 Area 2.
1986	West Lake Landfill	Existing and new wells around the inactive landfill on the western portion of the site, and the leachate retention pond, were included in a thorough hydrogeologic investigation. The hydrogeologic characterization concluded that three levels of the alluvial aquifer (shallow, intermediate, and deep) were in complete communication, and that groundwater flow was generally towards the northwest. Groundwater samples were collected and analyzed for volatile organic compounds, acid-base neutral extractables, pesticides and polychlorinated biphenyls, phenol, cyanide, and metals. Concentrations of certain parameters exceeded applicable standards, but the distribution was erratic and generally could not be attributed specifically to site activities. Concentrations of parameters which exceeded standards were likely to be diluted below standards prior to exposure to any downgradient uses.

TABLE 3-1
PREVIOUS INVESTIGATION SUMMARY
WEST LAKE LANDFILL

Year(s)	Investigation Conducted for:	Description
1986	Nuclear Regulatory Commission	Eighteen groundwater monitoring wells were sampled and analyzed for radionuclides.
1989 and 1991	Environmental Protection Agency	A review of historical aerial photographs, from 1941 through 1991, was conducted to identify areas of potential environmental concern. Solid waste and mine spoils areas were identified.
1989 to Present	Laidlaw Waste Systems	Groundwater samples were collected from wells throughout the site on an intermittent basis, focussing specifically on wells around the active landfill area in recent years. Samples were analyzed for a variable list of parameters, including general inorganics, metals, radionuclides, volatile organic compounds, pesticides, herbicides, polychlorinated biphenyls, cyanide, and phenol.
1990-1991	Earth City Industrial Park	An investigation of potential radiological impacts to neighboring properties was conducted in three phases. Radiological contamination reportedly originating from OU-1 Area 2 was identified in soils at two hot spots near the property boundary.
1991	Agency for Toxic Substances and Disease Registry	A review of available information concluded that the site presented no apparent health hazard, although exposure could occur if groundwater contamination increased and migrated off-site.
1991	Laidlaw Waste Systems	A subsurface soil gas survey conducted in the vicinity of MW-F2 identified BTEX and TPH impacts to subsurface soils in an area extending 150 feet north and 300 feet south of MW-F2.
1992	Laidlaw Waste Systems	An environmental investigation for the development of a site Health and Safety Plan identified radon in the landfill gas collection system.
1992	Laidlaw Waste Systems	The slope of the berm along the western portion of the inactive landfill was reworked to 3H:1V, recovered, and revegetated.
1993	Laidlaw Waste Systems	A health impact assessment concluded that radiological contaminants from site sources were not a threat to site workers, the general public, or the environment.
1994	Laidlaw Waste Systems	A health assessment analyzed chemical constituents of the landfill gas collection system and concluded that landfill gas composition was similar to EPA-reported averages, and that exposures to site workers were below analytical detection limits.
1994	OU-1 Respondent Group	An overland gamma survey conducted in and in the immediate vicinity of OU-1 identified radiologically-contaminated hot spots both inside and outside of OU-1 boundaries, and recommended alteration of those boundaries.

TABLE 3-2
PIEZOMETER AND LEACHATE RISER RATIONALE
WEST LAKE LANDFILL

PZ-100-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-100-SS is used in conjunction with PZ-115-SS and PZ-208-SS in triangulation of water levels along the northern end of the sanitary landfill.
PZ-100-SD	Boring completed in the lower portion of the Salem/St. Louis Formation. PZ-100-SD is used in conjunction with PZ-100-SS and PZ-100-KS to determine vertical gradients along the northern end of the sanitary landfill.
PZ-100-KS	Boring completed into the Keokuk Formation. This boring was continuously sampled during drilling and geophysically logged upon reaching total depth. PZ-100-KS is used in conjunction with PZ-100-SS and PZ-100-SD to determine vertical gradients along the northern end of the sanitary landfill.
PZ-101-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-101-SS is used in conjunction with PZ-102-SS and PZ-200-SS in triangulation of water levels along the northeastern portion of the sanitary landfill.
PZ-102-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. Bentonite was observed in purge water produced during development of PZ-102-SS, suggesting that the integrity of the piezometer was compromised. PZ-102-SS was replaced by PZ-102R-SS.
PZ-102R-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-102R-SS replaces PZ-102-SS. PZ-102R-SS is used in conjunction with PZ-101-SS and PZ-200-SS in triangulation of water levels along the northeastern portion of the sanitary landfill.
PZ-103-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-103-SS is used in conjunction with PZ-201-SS and PZ-202-SS in triangulation of water levels along the eastern portion of the sanitary landfill.
PZ-104-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-104-SS is used in conjunction with PZ-105-SS and PZ-203-SS in triangulation of water levels along the southeastern portion of the sanitary landfill.
PZ-104-SD	Boring completed in the lower portion of the Salem/St. Louis Formation. PZ-104-SD is used in conjunction with PZ-104-SS and PZ-104-KS to determine vertical gradients along the southeastern edge of the sanitary landfill. This boring was geophysically logged from ground surface to top of Warsaw Formation.
PZ-104-KS	Boring completed into the Keokuk Formation. This boring was continuously sampled during drilling and geophysically logged from top of Warsaw Formation to total depth upon reaching total depth. PZ-104-KS is used in conjunction with PZ-104-SS and PZ-104-SD to determine vertical gradients along the southeastern end of the sanitary landfill.

TABLE 3-2
PIEZOMETER AND LEACHATE RISER RATIONALE
WEST LAKE LANDFILL

PZ-105-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-105-SS is used in conjunction with PZ-106-SS, PZ-204-SS and LCS-2 in triangulation of water levels near the active landfill.
PZ-106-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-106-SS is used in conjunction with PZ-105-SS, PZ-204-SS, and LCS-2 in triangulation of water levels near the active landfill.
PZ-106-SD	Boring completed in the lower portion of the Salem/St. Louis Formation. PZ-106-SD is used in conjunction with PZ-106-SS and PZ-106-KS to determine vertical gradients along the southern edge of the sanitary landfill.
PZ-106-KS	Boring completed into the Keokuk Formation. This boring was continuously sampled during drilling and geophysically logged upon reaching total depth. PZ-106-KS is used in conjunction with PZ-106-SS and PZ-106-SD to determine vertical gradients along the southern end of the sanitary landfill.
PZ-107-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-107-SS is used in conjunction with PZ-106-SS, LCS-4, and PZ-205-SS in triangulation of water levels near the southwestern corner of the sanitary landfill.
PZ-108-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-108-SS is used in conjunction with PZ-109-SS and PZ-206-SS in triangulation of water levels near the northwestern corner of the sanitary landfill.
PZ-109-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-109-SS is used in conjunction with PZ-108-SS and PZ-206-SS in triangulation of water levels near the old quarry.
PZ-110-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-110-SS assists in defining the location of the edge of the alluvial valley.
PZ-111-SD	Boring completed in the lower portion of the Salem/St. Louis Formation. PZ-111-SD is used in conjunction with MW-F1S, MW-F1D, and PZ-111-KS to determine vertical gradients along the western edge of the sanitary landfill.
PZ-111-KS	Boring completed into the Keokuk Formation. This boring was continuously sampled during drilling and geophysically logged upon reaching total depth. PZ-111-KS is used in conjunction with PZ-106-SD, MW-F1S, and MW-F1D to determine vertical gradients along the western edge of the sanitary landfill.

TABLE 3-2
PIEZOMETER AND LEACHATE RISER RATIONALE
WEST LAKE LANDFILL

PZ-112-AS	Shallow boring completed in the alluvium. This boring was continuously sampled during drilling. This boring assists in determining the potentiometric surface between the inactive landfill to the west and the sanitary landfill to the east.
PZ-113-AS	Shallow boring completed in the alluvium. PZ-113-AS is used in conjunction with PZ-207-AS and S-84 in triangulation of water levels between the demolition landfill and the sanitary landfill.
PZ-113-AD	Boring completed at the base of the alluvium. PZ-113-AD is used in conjunction with PZ-113-AS to determine vertical gradients between the demolition landfill and the sanitary landfill.
PZ-113-SS	Boring completed 50 feet into the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-113-SS is used in conjunction with PZ-113-AS and PZ-113-AD to determine vertical gradients between the demolition landfill and the sanitary landfill.
PZ-114-AS	Shallow boring completed in the alluvium. This boring was continuously sampled during drilling. PZ-114-AS is intended to provide potentiometric surface data north of the sanitary landfill.
PZ-115-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-115-SS is used in conjunction with PZ-100-SS and PZ-208-SS in triangulation of water levels along the northern end of the sanitary landfill.
PZ-116-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-116-SS is used in conjunction with PZ-105-SS and PZ-204A-SS in triangulation of water levels along the southern end of the sanitary landfill.
PZ-200-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-200-SS is used in conjunction with PZ-101-SS and PZ-102-SS in triangulation of water levels along the northeastern portion of the sanitary landfill. PZ-200-SS will also be used to determine landfill gas concentrations.
PZ-201-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-201-SS is used in conjunction with PZ-103-SS and PZ-202-SS in triangulation of water levels along the eastern portion of the sanitary landfill. PZ-201-SS will also be used to determine landfill gas concentrations.
PZ-201A-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-201A-SS is used to confirm groundwater level measurements in the adjacent PZ-201-SS.

TABLE 3-2
PIEZOMETER AND LEACHATE RISER RATIONALE
WEST LAKE LANDFILL

PZ-202-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-202-SS is used in conjunction with PZ-103-SS and PZ-201-SS in triangulation of water levels along the eastern portion of the sanitary landfill.
PZ-203-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-203-SS will be used in conjunction with PZ-104-SS and PZ-105-SS in triangulation of water levels along the southeastern portion of the sanitary landfill.
PZ-204-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-204-SS is used in conjunction with PZ-105-SS, PZ-106-SS and LCS-2 in triangulation of water levels near the active landfill. PZ-204-SS will also be used to determine landfill gas concentrations.
PZ-204A-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-204A-SS is used to confirm groundwater levels in the adjacent PZ-204-SS.
PZ-205-AS	Shallow boring completed in the alluvium. PZ-205-AS is used in conjunction with PZ-205-SS to determine vertical gradients near the southwestern corner of the sanitary landfill.
PZ-205-SS	Deep boring completed 50 feet into the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-205-SS is used in conjunction with PZ-106-SS, PZ-107-SS, and LCS-4 in triangulation of water levels near the southwestern corner of the sanitary landfill.
PZ-206-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-206-SS is used in conjunction with PZ-108-SS and PZ-109-SS in triangulation of water levels near the northwestern corner of the sanitary landfill.
PZ-207-AS	Shallow boring completed in the alluvium. This boring was continuously sampled during drilling. PZ-207-AS is intended to define the hydrogeologic conditions between the demolition landfill and the sanitary landfill as well as to allow triangulation of water levels between the two landfills in conjunction with PZ-113-AS and S-84.
PZ-208-SS	Shallow boring completed in the Salem/St. Louis Formation. This boring was continuously sampled during drilling. PZ-208-SS is used in conjunction with PZ-100-SS and PZ-115-SS in triangulation of water levels along the northern end of the sanitary landfill.
PZ-300-AS	Shallow boring completed in the alluvium. PZ-300-AS is intended to provide background groundwater quality data. The well was decommissioned in April 1996.
PZ-300-AD	Boring completed to the base of the alluvium and is intended to provide background groundwater quality data. PZ-300-AD was decommissioned in April 1996.

TABLE 3-2
PIEZOMETER AND LEACHATE RISER RATIONALE
WEST LAKE LANDFILL

PZ-300-SS	Shallow boring completed in the Salem/St. Louis Formation. PZ-300-SS provided vertical gradient information between the alluvium and the bedrock in this background setting. The well was decommissioned in April 1996.
PZ-301-SS	Shallow boring completed in the Salem/St. Louis Formation. This piezometer provides supplemental background data for the upper and lower Salem/St. Louis Formations, respectively.
PZ-302-AS	Shallow boring completed in the alluvium. PZ-302-AS is used in conjunction with PZ-302-AI to provide hydraulic head data immediately upgradient of the landfill materials.
PZ-302-AI	Intermediate boring completed in the alluvium. PZ-302-AI is used in conjunction with PZ-300-AS to provide hydraulic head data immediately upgradient of the landfill materials.
PZ-303-AS	Shallow boring completed in the alluvium. PZ-303-AS is intended to provide information on the extent and magnitude of petroleum product impacts near monitoring well MW-F2.
PZ-304-AS	Shallow boring completed in the alluvium. PZ-304-AS is used in conjunction with PZ-304-AI to determine hydraulic head near the Earth City stormwater retention feature, to compare water levels to leachate levels, and to determine vertical gradients at the facility edge.
PZ-304-AI	Intermediate boring completed in the alluvium. PZ-304-AI is used in conjunction with PZ-304-AS to determine hydraulic head near the Earth City stormwater retention feature, to compare water levels to leachate levels, and to determine vertical gradients at the facility edge.
PZ-305-AI	Intermediate boring completed in the alluvium. PZ-305-AI was installed in the center of the site to allow triangulation across the western portion of the site.
LR-100	Shallow boring completed in inactive landfill waste. LR-100 is used to target potential source areas in the inactive landfill.
LR-101	Intermediate boring where no liquid was encountered. LR-101 is used to target potential source areas in the inactive landfill. Riser was not completed.
LR-102	Intermediate boring completed in inactive landfill waste. LR-102 is used to target potential source areas in the inactive landfill.
LR-103	Shallow boring completed in the alluvium. LR-103 was installed east of the inactive landfill to target two potential source areas.

TABLE 3-2
PIEZOMETER AND LEACHATE RISER RATIONALE
WEST LAKE LANDFILL

LR-104	Shallow boring completed in the alluvium. LR-104 was installed east of the inactive landfill to target two potential source areas.
LR-105	Shallow boring completed in inactive landfill waste.

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TABLE 3-3
PIEZOMETER AND LEACHATE RISER SUMMARY
WEST LAKE LANDFILL

Piezometer	Location		Elevation		Screened Interval					Surface Casing		
			Top of	Ground	Depth		Screen	Elevation				
	Northing	Easting	PVC	Surface	Bottom	Top	Length	Bottom	Top	Diameter	Depth	Rationale
PZ-100-SS	1068867.81	517175.03	485.84	484.4	93.60	73.96	19.64	390.75	410.39	NA		
PZ-100-SD	1068851.79	517195.45	485.82	484.4	244.60	234.80	9.80	239.75	249.55	NA		
PZ-100-KS	1068842.03	517211.63	485.64	483.8	383.80	374.00	9.80	99.96	109.76	NA		
PZ-101-SS	1068472.89	516622.94	476.68	474.9	139.28	129.48	9.80	335.61	345.41	NA		
PZ-102-SS	1068087.67	516887.97	483.85	482.1	89.50	79.70	9.80	392.55	402.35	NA		
PZ-102R-SS	1068131.86	516858.81	485.58	484.5	89.63	79.83	9.80	394.87	404.67	NA		
PZ-103-SS	1067660.40	516723.54	480.17	477.8	144.50	134.70	9.80	333.28	343.08	NA		
PZ-104-SS	1067028.01	516847.19	483.63	481.6	144.30	134.50	9.80	337.26	347.06	NA		
PZ-104-SD	1067013.26	516834.43	483.69	482.1	245.00	235.20	9.80	237.10	246.90	NA		
PZ-104-KS	1066993.15	516820.50	484.04	482.3	407.17	397.37	9.80	75.15	84.95	6 in.	1.00-249.00	isolate formations above Warsaw Formation
PZ-105-SS	1066421.35	516230.23	483.61	481.2	148.30	138.50	9.80	332.92	342.72	6 in.	1.50-45.00	isolate wet sands
PZ-106-SS	1066726.29	515399.94	462.70	461.0	165.10	155.30	9.80	295.85	305.65	NA		
PZ-106-SD	1066715.14	515415.96	463.42	461.5	200.59	190.79	9.80	260.86	270.66	NA		
PZ-106-KS	1066703.87	515432.10	464.26	461.8	373.57	363.75	9.80	88.20	98.02	6 in.	1.00-204.00	isolate formations above Warsaw Formation
PZ-107-SS	1067163.45	515254.52	464.66	462.6	102.40	92.60	9.80	360.23	370.03	6 in.	1.00-55.00	isolate waste and fine sands
PZ-108-SS	1067678.37	515972.61	456.20	454.1	143.35	133.54	9.80	310.77	320.58	NA		
PZ-109-SS	1068011.70	516144.36	458.50	456.8	135.50	125.70	9.80	321.27	331.07	NA		
PZ-110-SS	1068336.09	515919.72	458.91	456.8	110.70	100.90	9.80	346.14	355.94	6 in.	1.00-61.00	isolate fine sands
PZ-111-SD	1068638.11	515834.57	461.55	459.2	209.20	199.40	9.80	250.02	259.82	6 in.	1.00-98.00	isolate fine sands
PZ-111-KS	1068620.78	515850.23	460.87	459.2	366.96	357.15	9.80	92.22	102.03	10 in. 6 in.	0.50-83.80 1.00-215.30	isolate fine sands isolate formations above Warsaw Formation
PZ-112-AS	1069002.00	515674.01	459.83	457.9	34.40	29.60	4.80	423.53	428.33	NA		

Notes provided on page 3

TABLE 3-3
PIEZOMETER AND LEACHATE RISER SUMMARY
WEST LAKE LANDFILL

	Location		Elevation		Screened Interval					Surface Casing		
			Top of	Ground	Depth		Screen	Elevation				
Piezometer	Northing	Easting	PVC	Surface	Bottom	Top	Length	Bottom	Top	Diameter	Depth	Rationale
PZ-113-AS	1069224.31	515747.72	461.42	459.9	38.70	28.90	9.80	421.22	431.02	NA		
PZ-113-AD	1069233.33	515759.85	461.46	459.9	108.40	98.60	9.80	351.46	361.26	NA		
PZ-113-SS	1069242.39	515776.57	461.77	460.0	158.37	148.57	9.80	301.59	311.39	6 in.	0.50-115.00	isolate alluvial sands
PZ-114-AS	1069418.88	516768.25	451.31	449.8	29.70	19.90	9.80	420.08	429.88	NA		
PZ-115-SS	1069408.54	516755.35	452.30	450.6	84.48	74.68	9.80	366.13	375.93	6 in.	1.00-39.00	isolate alluvial sands
PZ-116-SS	1066410.28	515843.88	484.87	483.1	161.00	151.40	9.60	322.07	331.67	NA		
PZ-200-SS	1068496.19	516972.20	485.63	483.6	97.64	9.62	88.02	385.97	473.99	NA		
PZ-201-SS	1067819.55	516862.06	480.33	478.0	88.31	9.75	78.56	389.70	468.26	NA		
PZ-201A-SS	1067831.76	516846.40	480.16	478.4	89.80	80.00	9.80	388.55	398.35	NA		
PZ-202-SS	1067320.25	517101.58	481.17	479.0	89.10	40.20	48.90	389.91	438.81	6 in.	1.00-34.00	isolate fine sands
PZ-203-SS	1066661.50	516607.70	486.59	484.2	109.40	99.60	9.80	374.78	384.58	6 in.	1.00-56.10	isolate alluvial sands
PZ-204-SS	1066426.61	515533.49	469.63	467.0	89.35	10.95	78.40	377.68	456.08	NA		
PZ-204A-SS	1066429.82	515556.28	468.16	466.7	89.10	79.50	9.60	377.56	387.16	NA		
PZ-205-AS	1067463.60	515463.34	460.99	459.3	48.35	38.55	9.80	410.98	420.78	10 in.	0.50-29.00	isolate waste
PZ-205-SS	1067483.54	515477.78	461.78	459.5	98.37	88.57	12.80	360.96	370.76	6 in.	1.00-54.00	isolate waste and fine sands
PZ-206-SS	1068030.83	515809.45	460.20	458.4	124.80	115.00	9.80	333.58	343.38	6 in.	1.00-52.00	isolate fine sands and potential UST impacts
PZ-207-AS	1069644.67	516037.64	463.57	461.9	39.70	34.90	4.80	422.18	426.98	NA		
PZ-208-SS	1069219.14	517169.45	474.25	472.5	98.50	88.70	9.80	374.03	383.83	NA		

Notes provided on page 3

TABLE 3-3
PIEZOMETER AND LEACHATE RISER SUMMARY
WEST LAKE LANDFILL

	Location		Elevation		Screened Interval					Surface Casing		
			Top of	Ground	Depth		Screen	Elevation				
Piezometer	Northing	Easting	PVC	Surface	Bottom	Top	Length	Bottom	Top	Diameter	Depth	Rationale
PZ-300-AS	1065198.44	513867.83	450.66	448.5	19.70	9.90	9.80	428.80	438.60	NA		
PZ-300-AD	1065213.84	513828.06	449.62	448.1	41.90	37.10	4.80	406.20	411.00	NA		
PZ-300-SS	1065204.75	513849.81	449.60	448.4	93.70	83.90	9.80	354.70	364.50	6 in.	0.80-46.00	seal off alluvial materials
PZ-301-SS	1064801.68	515516.99	514.71	513.1	106.70	150.90	9.80	352.40	362.20	NA		
PZ-302-AS	1067197.73	514737.29	451.42	449.2	22.00	12.20	9.80	427.20	437.00	NA		
PZ-302-AI	1067210.24	514720.49	451.15	450.0	42.40	32.60	9.80	407.60	417.40	NA		
PZ-303-AS	1067763.32	514425.53	453.18	450.8	25.80	16.00	9.80	425.00	434.80	NA		
PZ-304-AS	1068146.47	514434.57	453.71	451.4	26.90	17.10	9.80	424.50	434.30	NA		
PZ-304-AI	1068125.91	514434.70	454.02	451.6	48.80	39.00	9.80	402.80	412.60	NA		
PZ-305-AI	1068064.93	515633.57	459.28	547.6	63.00	53.20	9.80	394.60	404.40	NA		
PZ-1201-SS	1067302.42	516903.56	482.42	480.4	147.30	137.70	9.60	333.11	342.71	NA	2.60-53.00	seal off alluvial materials
Leachate Riser												
LR-100	1067293.73	514893.56	469.12	467.2	24.50	19.70	4.80	442.70	447.50	NA		
LR-101	1068402.25	514718.41	NA	NA	NA	NA	NA	NA	NA	NA		well not installed
LR-102	1068937.21	514788.13	513.52	512.0	59.70	54.90	4.80	452.30	457.10	NA		
LR-103	1068527.38	515217.07	461.28	460.1	38.40	28.60	9.80	421.70	431.50	NA		
LR-104	1068078.63	515623.34	459.73	458.0	38.20	28.40	9.80	419.80	429.60	NA		
LR-105	1067709.56	514524.56	486.79	484.2	36.00	26.20	9.80	448.20	458.00	NA		

NOTES: Survey data provided by Sherbut-Carson & Associates, P.C.
Horizontal Datum: Missouri State Plane Coordinate System
Vertical Datum: USGS North American Vertical Datum
All measurements provided in feet, except as indicated
PVC = Polyvinyl chloride casing, 2-inch ID Schedule 80
NA = Not applicable

TABLE 4-1
SUMMARY OF SOIL DATA
WEST LAKE LANDFILL

BORING NO.	SAMPLE NO.	SAMPLE DEPTH (ft)	USCS SOIL CLASSI-FICATION	NATURAL MOISTURE %	ATTERBERG LIMITS				GRAIN SIZE DISTRIBUTION		SPECIFIC GRAVITY	VOID RATIO	UNIT WEIGHT OF PCF		ADDITIONAL TESTS COMMENTS (SEE NOTES)
					L.L.	P.L.	P.I.	S.L.	% FINER NO. 4 SIEVE	% FINER NO. 200 SIEVE			WET	DRY	
PZ-100-KS	--	4-6,6-8	CL	--	40	24	16	--	100	89	2.62	--	--	--	--
PZ-101-SS	--	4-6,6-8	CL	24.4	38	22	16	--	100	92	2.68	--	--	--	PERM
PZ-102-SS	--	4-6,8-10	CL-ML	28.2	39	25	14	--	100	99	2.69	--	--	--	PERM
PZ-102R-SS	--	12-14,14-16	CL	--	34	24	10	--	100	96	2.76	--	--	--	--
PZ-102R-SS	--	18-20	--	--	--	--	--	--	100	8	2.69	--	--	--	--
PZ-102R-SS	--	28-30	--	--	--	NP	NP	--	--	--	--	--	--	--	--
PZ-103-SS	--	12-14,14-16	ML	28.3	--	NP	NP	--	100	97	2.67	--	--	--	PERM
PZ-104-KS	--	4-6,6-8	CL	23.6	46	25	21	--	100	94	2.66	--	--	--	PERM
PZ-105-SS	--	8-10,10-12	CL	--	40	22	18	--	100	99	2.71	--	--	--	--
PZ-105-SS	--	18-20	--	--	--	NP	NP	--	--	--	--	--	--	--	--
PZ-105-SS	--	30-32	--	--	--	--	--	--	100	11	--	--	--	--	--
PZ-106-KS	--	6-8,8-10	CL	22.2	47	20	27	--	100	79	2.77	--	--	--	PERM
PZ-106-KS	GTS-1	201.9-202.5	--	--	--	--	--	--	--	--	--	--	--	--	PERM
PZ-106-KS	GTS-2	229.6-230.1	--	--	--	--	--	--	--	--	--	--	--	--	PERM
PZ-107-SS	--	22-24	--	--	--	--	--	--	100	99	2.69	--	--	--	--
PZ-108-SS	--	16-18	--	--	--	--	--	--	100	65	2.77	--	--	--	--
PZ-109-AS	--	10-12	CL	28.1	44	19	25	--	100	82	2.61	--	--	--	--
PZ-110-SS	--	4-6	--	--	31	22	9	--	--	--	--	--	--	--	--
PZ-110-SS	--	52-54	--	--	--	--	--	--	100	11	2.67	--	--	--	--
PZ-112-AS	--	34-36	SP	14.0	--	--	--	--	99	3	--	--	--	--	--

TABLE 4-1
SUMMARY OF SOIL DATA
WEST LAKE LANDFILL

BORING NO.	SAMPLE NO.	SAMPLE DEPTH (ft)	USCS SOIL CLASSIFICATION	NATURAL MOISTURE %	ATTERBERG LIMITS				GRAIN SIZE DISTRIBUTION		SPECIFIC GRAVITY	VOID RATIO	UNIT WEIGHT OF PCF		ADDITIONAL TESTS COMMENTS (SEE NOTES)
					L.L.	P.L.	P.I.	S.L.	% FINER NO. 4 SIEVE	% FINER NO. 200 SIEVE			WET	DRY	
PZ-113-AS	--	4-6	--	14.2	26	18	8	--	--	--	--	--	--	--	--
PZ-113-AS	--	6-8,8-10	CL	--	35	16	19	--	99	73	2.69	--	--	--	--
PZ-113-AS	--	10-12	CL	20.1	32	23	9	--	100	83	2.62	--	--	--	--
PZ-113-AS	--	28-30	--	--	--	--	--	--	100	17	--	--	--	--	--
PZ-113-AS	--	34-36	SP-SM	18.0	--	--	--	--	100	7	--	--	--	--	--
PZ-113-AS	--	94-96	--	--	--	--	--	--	98	6	--	--	--	--	--
PZ-114-AS	--	12-14	CL	33.2	40	24	16	--	97	87	2.51	--	--	--	--
PZ-114-AS	--	24-26	--	20.3	--	--	--	--	100	28	--	--	--	--	--
PZ-115-SS	--	30-32	--	--	--	--	--	--	100	6	2.72	--	--	--	--
PZ-116-SS	--	7-9	--	--	34	23	11	--	--	--	--	--	--	--	--
PZ-116-SS	--	15-17	--	--	--	NP	NP	--	--	--	--	--	--	--	--
PZ-116-SS	--	29-31	--	--	--	--	--	--	100	2	--	--	--	--	--
PZ-200-SS	--	6-8,8-10	CL-ML	27.5	36	24	12	--	100	98	2.64	--	--	--	PERM
PZ-201-SS	--	24-26,26-28	ML	34.5	--	NP	NP	--	100	89	2.62	--	--	--	PERM
PZ-202-SS	--	6-8,8-10	CL	26.7	45	24	21	--	100	97	2.74	--	--	--	PERM
PZ-203-SS	--	2-4	--	--	32	21	11	--	--	--	--	--	--	--	--
PZ-203-SS	--	8-10,10-12	ML	--	36	25	11	--	100	97	2.85	--	--	--	--
PZ-203-SS	--	38-40	--	--	--	--	--	--	100	13	--	--	--	--	--
PZ-204-SS	--	8-10,10-12	ML	--	--	NP	NP	--	100	77	2.68	--	--	--	--

TABLE 4-1
SUMMARY OF SOIL DATA
WEST LAKE LANDFILL

BORING NO.	SAMPLE NO.	SAMPLE DEPTH (ft)	USCS SOIL CLASSI-FICATION	NATURAL MOISTURE %	ATTERBERG LIMITS				GRAIN SIZE DISTRIBUTION		SPECIFIC GRAVITY	VOID RATIO	UNIT WEIGHT OF PCF		ADDITIONAL TESTS COMMENTS (SEE NOTES)
					L.L.	P.L.	P.I.	S.L.	% FINER NO. 4 SIEVE	% FINER NO. 200 SIEVE			WET	DRY	
PZ-205-SS	--	28-30	--	--	--	--	--	--	100	90	2.64	--	--	--	--
PZ-205-AS	--	31-33	ML	--	--	NP	NP	--	99	79	2.68	--	--	--	--
PZ-205-AS	--	41-43,43-45	ML	--	--	NP	NP	--	100	66	2.81	--	--	--	--
PZ-206-SS	--	8-10,32-34	SP-SM	--	--	NP	NP	--	100	11	2.62	--	--	--	--
PZ-207-AS	--	36-38	SP	17.0	--	--	--	--	100	3	--	--	--	--	--
PZ-208-SS	--	2-4	--	--	40	18	22	--	--	--	--	--	--	--	--
PZ-208-SS	--	8-10,10-12	CL	--	34	22	12	--	100	60	--	--	--	--	--
PS-1	--	-10	CL	23.0	47	17	30	--	100	99	2.74	--	--	--	P, PERM
PS-2	--	-7	CL	25.9	39	22	17	--	100	98	2.81	--	--	--	P, PERM
LR-103	--	20-22	CH	37.4	80	29	51	--	100	99	--	--	--	--	PERM

NOTES:

LL = LIQUID LIMIT
PL = PLASTIC LIMIT
PI = PLASTIC INDEX
SL = SHRINKAGE LIMIT

T = TRIAXIAL TEST
U = UNCONFINED COMPRESSION TEST
C = CONSOLIDATION TEST
P = PROCTOR TEST
DS = DIRECT SHEAR TEST
Perm = PERMEABILITY

TABLE 4-2
SUMMARY OF FLEXIBLE WALL PERMEABILITY TEST RESULTS
WEST LAKE LANDFILL

SAMPLE NUMBER	PZ-101-SS 6-8	PZ-102-SS 4-6	PZ-103-SS 14-16	PZ-104-KS 6-8	PZ-106-KS 6-8	PZ-106-KS GTS-1 201.9-202.5	PZ-106-KS GTS-2 229.6-230.1	PZ-200-SS 6-8	PZ-201-SS 26-28	PZ-202-SS 6-8	PS-1 10	PS-2 7	LR-103 [illegible]
Sample Length (cm)	7.99	8.82	7.73	9.11	8.89	7.63	7.66	9.59	8.11	8.08	9.56	9.55	[illegible]
Sample Diameter (cm)	7.22	7.07	7.18	7.14	7.14	4.50	4.47	7.17	7.13	7.10	7.23	7.24	7.22
Sample Dry Density (pcf)	91.7	92.2	97.7	95.7	103.0	151.9	148.0	95.3	86.4	96.4	100.8	101.7	79.9
Maximum Dry Density (pcf)	--	--	--	--	--	--	--	--	--	--	105.0	106.0	--
Compaction (%)	--	--	--	--	--	--	--	--	--	--	96	96	--
Initial Moisture Content (%)	24.4	28.2	28.3	23.6	22.2	4.5	4.4	27.5	34.5	26.7	18.4	17.5	37.4
Optimum Moisture Content (%)	--	--	--	--	--	--	--	--	--	--	19.0	17.5	17.5
Effective Stress (psi)	6	5	13	6	6	153	170	6	23	6	5	5	5
Back Pressure (psi)	94	95	87	94	94	98	88	94	77	94	95	95	95
Gradient	2	9	4	24	5	129	94	4	14	10	6	10	[illegible]
Average Permeability (cm/sec)	$3x10^{-4}$	$8x10^{-7}$	$2x10^{-6}$	$2x10^{-7}$	$3x10^{-6}$	$<1.1x10^{-10}$	$1.5x10^{-10}$	$2x10^{-6}$	$3x10^{-6}$	$3x10^{-7}$	$2x10^{-7}$	$3x10^{-7}$	$2x10^{-4}$

TABLE 4-3
WATER LEVEL ELEVATION SUMMARY
WEST LAKE LANDFILL

Monitoring Location	Date						
	June 27, 1995	July 26, 1995	Aug. 26, 1995	Sept. 30, 1995	July 12, 1996	Nov. 18, 1995	Dec. 14, 1995
	Groundwater Elevation						
Shallow Alluvial Piezometers							
PZ-112-AS	436.12	435.12	434.67	432.84	434.31	431.84	431.15
PZ-113-AS	435.64	435.30	434.63	432.91	434.39	431.81	431.18
PZ-114-AS	435.94	435.35	434.90	433.06	434.46	431.93	431.23
PZ-205-AS	434.41	434.33	434.06	432.52	433.71	431.66	431.19
PZ-207-AS	435.94	435.41	434.91	433.02	434.52	431.87	431.19
PZ-300-AS	NA	NA	NA	NA	NA	435.50	434.94
PZ-302-AS	NA	NA	NA	NA	434.12	432.08	431.86
PZ-303-AS	NA	NA	NA	NA	434.23	432.01	431.74
PZ-304-AS	NA	NA	NA	NA	434.14	431.91	431.63
Intermediate Alluvial Piezometers							
PZ-302-AI	NA	NA	NA	NA	434.05	432.00	431.73
PZ-304-AI	NA	NA	NA	NA	434.2	431.98	431.66
PZ-305-AI	NA	NA	NA	NA	434.17	431.80	431.34
Deep Alluvial Piezometers							
PZ-113-AD	435.68	435.13	433.74	432.89	434.35	431.82	431.18
PZ-300-AD	NA	NA	NA	NA	NA	432.78	432.41
St. Louis/Upper Salem Hydrologic Unit Piezometers							
PZ-100-SS	405.36	416.06	415.23	414.35	412.94	413.85	413.68
PZ-101-SS	393.23	394.58	393.37	390.00	387.08	387.58	386.76
PZ-102-SS	413.54	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive

Notes provided on pages 4 and 8

TABLE 4-3
WATER LEVEL ELEVATION SUMMARY
WEST LAKE LANDFILL

Monitoring Location	Date						
	June 27, 1995	July 26, 1995	Aug. 26, 1995	Sept. 30, 1995	July 12, 1996	Nov. 18, 1995	Dec. 14, 1995
	Groundwater Elevation						
St. Louis/Upper Salem Hydrologic Unit Piezometers--Continued							
PZ-102R-SS	403.09	424.30	424.87	422.80	420.60	421.63	420.78
PZ-103-SS	363.03	373.02	363.73	360.95	363.42	361.05	360.15
PZ-104-SS	340.67	360.04	366.22	361.01	371.1	360.41	360.55
PZ-105-SS	336.26	339.83	352.45	346.80	370.61	342.76	342.53
PZ-106-SS	359.72	357.60	364.20	349.41	368.46	350.01	342.64
PZ-107-SS	434.52	434.30	434.00	432.36	433.55	431.57	431.12
PZ-108-SS	368.99	368.99	367.02	352.14	358.19	356.78	347.44
PZ-109-SS	370.70	373.74	360.45	359.20	360.57	355.12	351.80
PZ-110-SS	413.76	433.53	433.27	431.57	432.09	430.58	430.11
PZ-113-SS	435.70	435.23	434.79	433.00	434.46	431.94	427.33
PZ-115-SS	426.75	424.83	424.18	417.06	421.85	411.71	407.86
PZ-116-SS	NA	346.79	356.46	338.17	365.51	331.43	330.07
PZ-200-SS	415.05	415.45	415.59	414.38	412.28	412.78	412.91
PZ-201-SS	456.42	455.53	454.86	453.55	453.27	452.98	452.80
PZ-201A-SS	415.03	414.63	414.38	412.94	413.08	412.57	412.12
PZ-202-SS	444.36	444.78	444.14	441.33	447.77	439.70	439.13
PZ-203-SS	(Dry)	(Dry)	(Dry)	(Dry)	375.52	(Dry)	(Dry)
PZ-204-SS	442.82	441.49	438.10	431.82	440.23	430.57	429.71
PZ-204A-SS	NA	405.65	405.53	404.05	405.53	403.55	403.45
PZ-205-SS	424.46	424.04	423.45	421.75	422.97	421.28	420.50

Notes provided on pages 4 and 8

TABLE 4-3
WATER LEVEL ELEVATION SUMMARY
WEST LAKE LANDFILL

Monitoring Location	Date						
	June 27, 1995	July 26, 1995	Aug. 26, 1995	Sept. 30, 1995	July 12, 1996	Nov. 18, 1995	Dec. 14, 1995
	Groundwater Elevation						
St. Louis/Upper Salem Hydrologic Unit Piezometers--Continued							
PZ-206-SS	420.04	419.04	418.22	415.49	418.89	415.19	NA
PZ-208-SS	NA	436.44	435.60	431.63	434.73	428.83	426.97
PZ-300-SS	NA	NA	NA	NA	****	428.32	427.80
PZ-301-SS	NA	NA	NA	NA	428.76	357.19	384.19
PZ-1201-SS	NA	392.33	365.30	377.98	380.34	374.88	374.88
MW-1206	368.19	367.12	367.86	351.67	351.67	362.46	348.15
Deep Salem Piezometers							
PZ-100-SD	394.61	370.68	381.79	366.35	367.04	364.43	356.68
PZ-104-SD	359.05	356.64	362.97	344.33	367.77	341.90	339.05
PZ-106-SD	358.64	353.52	361.98	348.44	367.31	347.38	340.60
PZ-111-SD	373.70	423.87	428.55	432.22	433.46	431.47	430.93
MW-1204	333.83	330.01	357.27	305.57	332.89	303.18	309.24
MW-1205	352.28	357.38	296.81	341.10	****	317.88	337.07
Keokuk Piezometers							
PZ-100-KS	438.17	438.93	437.84	434.72	439.35	433.67	432.84
PZ-104-KS	444.63	444.74	444.27	441.98	447.4	440.77	440.42
PZ-106-KS	442.18	442.51	442.48	440.30	368.46	439.02	438.82
PZ-111-KS	441.58	441.91	442.01	440.39	443.66	439.14	438.85

Notes provided on pages 4 and 8

TABLE 4-3
WATER LEVEL ELEVATION SUMMARY
WEST LAKE LANDFILL

Monitoring Location	Date						
	June 27, 1995	July 26, 1995	Aug. 26, 1995	Sept. 30, 1995	July 12, 1996	Nov. 18, 1995	Dec. 14, 1995
	Leachate Elevation						
Leachate Risers							
LR-100	NA	NA	NA	NA	451.71	450.42	449.90
LR-102	NA	NA	NA	NA	453.82	452.38	452.31
LR-103	NA	NA	NA	NA	434.25	431.86	431.32
LR-104	NA	NA	NA	NA	434.15	432.20	431.35
LR-105	NA	NA	NA	NA	453.71	452.44	452.38
	Surface Water Elevation						
Staff Gauges							
SG-8	NA	NA	NA	NA	433.87	433.54	432.75
SG-9	NA	NA	NA	NA	433.87	433.54	432.75

NOTES:

NA = Not available. Water level data was not collected on the indicated date either because the piezometer, leachate riser, or staff gauge had not yet been installed, or development was not yet completed. An equipment malfunction prevented measurement of the water level in PZ-206-SS on December 14, 1995.

PZ-102-SS was replaced by PZ-102R-SS, and is inactive.

LR-101 was not installed because leachate was not present.

All elevations provided in feet above Mean Sea Level (MSL)

TABLE 4-3
WATER LEVEL ELEVATION SUMMARY
WEST LAKE LANDFILL

Monitoring Location	Date						
	Jan. 4, 1996	Feb. 6, 1996	Mar. 4, 1996	Apr. 3, 1996	May 3, 1996	June 13, 1996	July 12, 1996
	Groundwater Elevation						
Shallow Alluvial Piezometers							
PZ-112-AS	431.05	430.46	429.80	429.53	430.73	434.63	434.31
PZ-113-AS	431.07	430.47	429.93	429.48	430.79	432.74	434.39
PZ-114-AS	431.20	430.67	430.09	429.93	431.60	435.18	434.46
PZ-205-AS	430.98	430.54	431.04	429.85	430.68	433.79	433.71
PZ-207-AS	431.10	430.52	429.97	429.66	431.12	434.99	434.52
PZ-300-AS	434.11	434.03	433.72	434.02	****	****	****
PZ-302-AS	431.34	430.80	430.27	430.03	431.26	434.63	434.12
PZ-303-AS	431.28	430.64	430.03	429.77	430.99	434.37	434.23
PZ-304-AS	431.13	430.52	429.93	429.59	431.07	434.44	434.14
Intermediate Alluvial Piezometers							
PZ-302-AI	431.27	430.66	430.08	426.75	431.10	434.36	434.05
PZ-304-AI	431.16	430.57	429.96	429.62	431.13	434.48	434.20
PZ-305-AI	431.03	430.56	429.93	429.79	430.65	434.36	434.17
Deep Alluvial Piezometers							
PZ-113-AD	431.03	430.44	429.92	429.62	430.81	434.79	434.35
PZ-300-AD	432.12	431.44	430.73	430.63	****	****	****
St. Louis/Upper Salem Hydrologic Unit Piezometers							
PZ-100-SS	413.63	413.46	413.20	412.87	412.83	413.10	412.94
PZ-101-SS	387.48	385.28	385.58	385.24	385.09	377.47	387.08
PZ-102-SS	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive

Notes provided on page 4

TABLE 4-3
WATER LEVEL ELEVATION SUMMARY
WEST LAKE LANDFILL

Monitoring Location	Date						
	Jan. 4, 1996	Feb. 6, 1996	Mar. 4, 1996	Apr. 3, 1996	May 3, 1996	June 13, 1996	July 12, 1996
	Groundwater Elevation						
St. Louis/Upper Salem Hydrologic Unit Piezometers--Continued							
PZ-102R-SS	420.59	404.70	404.61	418.91	418.24	419.58	420.60
PZ-103-SS	361.47	362.30	362.01	362.85	363.71	364.44	363.42
PZ-104-SS	361.53	365.31	362.92	362.99	376.44	376.30	371.10
PZ-105-SS	343.21	357.52	350.46	356.22	376.83	376.59	370.61
PZ-106-SS	343.70	359.94	347.42	357.55	371.56	375.01	368.46
PZ-107-SS	430.90	430.24	429.58	429.35	430.34	433.79	433.55
PZ-108-SS	346.47	351.88	346.25	356.00	359.97	361.50	358.19
PZ-109-SS	350.40	350.84	350.87	350.78	352.41	358.18	360.57
PZ-110-SS	429.87	429.09	428.31	427.51	428.65	432.45	432.09
PZ-113-SS	431.16	430.58	430.06	429.65	430.89	434.81	434.46
PZ-115-SS	414.34	413.23	406.34	414.31	423.51	425.80	421.85
PZ-116-SS	330.68	351.62	346.13	337.96	353.41	364.27	365.51
PZ-200-SS	412.73	412.42	412.14	412.03	412.05	412.36	412.28
PZ-201-SS	452.45	452.24	452.21	451.88	451.69	452.34	453.27
PZ-201A-SS	412.13	411.92	411.92	412.06	412.03	412.58	413.08
PZ-202-SS	438.64	441.28	440.27	441.20	441.81	446.98	447.77
PZ-203-SS	(Dry)	(Dry)	(Dry)	(Dry)	377.56	379.04	375.52
PZ-204-SS	431.58	440.83	439.74	440.02	441.19	441.45	440.23
PZ-204A-SS	403.78	405.38	405.15	405.46	406.69	406.07	405.53
PZ-205-SS	420.28	419.93	419.10	419.11	420.13	423.25	422.97

Notes provided on page 4

TABLE 4-3
WATER LEVEL ELEVATION SUMMARY
WEST LAKE LANDFILL

Monitoring Location	Date						
	Jan. 4, 1996	Feb. 6, 1996	Mar. 4, 1996	Apr. 3, 1996	May 3, 1996	June 13, 1996	July 12, 1996
	Groundwater Elevation						
St. Louis/Upper Salem Hydrologic Unit Piezometers--Continued							
PZ-206-SS	414.13	413.86	413.53	413.80	414.81	419.31	418.89
PZ-208-SS	428.60	428.93	426.41	428.87	432.54	434.82	434.73
PZ-300-SS	427.50	427.88	426.56	426.58	****	****	****
PZ-301-SS	395.65	407.66	415.13	420.17	423.94	427.35	428.76
PZ-1201-SS	376.00	378.52	372.92	379.44	NM	378.82	380.34
MW-1206	348.17	359.29	350.53	359.27	****	****	****
Deep Salem Piezometers							
PZ-100-SD	355.04	363.01	357.73	372.88	367.82	375.93	367.04
PZ-104-SD	343.15	361.88	348.24	360.25	370.88	376.92	367.77
PZ-106-SD	341.52	356.82	346.26	350.17	364.81	369.43	367.31
PZ-111-SD	430.63	430.06	429.43	428.90	429.00	432.55	433.46
MW-1204	306.96	356.52	318.98	332.51	344.32	360.30	332.89
MW-1205	339.32	350.89	314.15	342.90	****	****	****
Keokuk Piezometers							
PZ-100-KS	432.69	435.10	433.96	435.71	435.56	438.84	439.35
PZ-104-KS	440.22	443.10	441.74	442.94	443.35	447.35	447.40
PZ-106-KS	438.61	440.70	439.91	440.50	440.68	442.63	444.46
PZ-111-KS	438.77	440.04	439.92	440.13	440.16	442.55	443.66

Notes provided on page 4

TABLE 4-3
WATER LEVEL ELEVATION SUMMARY
WEST LAKE LANDFILL

Monitoring Location	Date						
	Jan. 4, 1996	Feb. 6, 1996	Mar. 4, 1996	Apr. 3, 1996	May 3, 1996	June 13, 1996	July 12, 1996
	Leachate Elevation						
Leachate Risers							
LR-100	449.77	450.14	450.60	450.61	451.64	452.02	451.71
LR-102	452.28	452.18	452.22	452.51	452.30	454.20	453.82
LR-103	431.00	430.58	429.98	429.71	430.75	434.49	434.25
LR-104	431.01	430.56	429.95	429.82	430.59	434.37	434.15
LR-105	453.39	453.40	453.61	453.70	453.43	453.61	453.71
	Surface Water Elevation						
Staff Gauges							
SG-8	433.68	433.98	(Dry)	433.99	433.07	433.86	433.87
SG-9	433.68	433.98	(Dry)	433.97	433.02	433.86	433.87

NOTES:

NA = Not available. Water level data was not collected on the indicated date either because the piezometer, leachate riser, or staff gauge had not yet been installed, or development was not yet completed. An equipment malfunction prevented measurement of the water level in PZ-206-SS on December 14, 1995.

PZ-102-SS was replaced by PZ-102R-SS, and is inactive.
LR-101 was not installed because leachate was not present.
All elevations provided in feet above Mean Sea Level (MSL)

**** = Wells decommissioned in May.

TABLE 4-4
VERTICAL HYDRAULIC GRADIENTS - OCTOBER 28, 1995
WEST LAKE LANDFILL

Interval Monitored	Piezometer Pair	Δ H	Δ L	i_v
Shallow Alluvium to Intermediate Alluvium	PZ-302-AS/PZ-302-AI	432.34-432.16	432.40-412.50	0.009
Shallow Alluvium to Intermediate Alluvium	PZ-304-AS/PZ-304-AI	432.19-432.19	429.40-407.70	0
Shallow Alluvium to Deep Alluvium	PZ-113-AS/PZ-113-AD	432.19-432.28	425.92-356.36	-0.0013
Shallow Alluvium to Deep Alluvium	PZ-300-AS/PZ-300-AD	436.41-432.89	433.70-408.60	0.14
Shallow Alluvium to St. Louis/Salem	PZ-114-AS/PZ-115-SS	432.11-413.09	424.78-370.03	0.34
Shallow Alluvium to St. Louis/Salem	PZ-205-AS/PZ-205-SS	431.90-421.69	416.88-367.56	0.21
Deep Alluvium to St. Louis/Salem	PZ-113-AD/PZ-113-SS	432.28-432.29	356.36-306.36	-0.0002
Deep Alluvium to St. Louis/Salem	PZ-300-AD/PZ-300-SS	432.89-428.62	408.60-359.61	0.09
St. Louis/Salem to Deep Salem	PZ-100-SS/PZ-100-SD	414.04-363.78	400.57-244.65	0.32
St. Louis/Salem to Deep Salem	PZ-104-SS/PZ-104-SD	360.34-341.68	342.16-241.25	0.18
St. Louis/Salem to Deep Salem	PZ-106-SS/PZ-106-SD	350.41-346.40	300.75-265.75	0.11
Deep Salem to Keokuk	PZ-100-SD/PZ-100-KS	363.78-433.90	244.65-104.86	-0.50
Deep Salem to Keokuk	PZ-104-SD/PZ-104-KS	341.68-440.99	241.25-80.05	-0.62
Deep Salem to Keokuk	PZ-106-SD/PZ-106-KS	346.40-439.47	265.75-93.07	-0.53
Deep Salem to Keokuk	PZ-111-SD/PZ-111-KS	431.90-439.68	254.92-97.18	-0.05

NOTES:

Δ H = Head differential
Δ L = Distance differential
i_v = vertical gradient
(-) The negative sign is used in the context of this table to represent an upward gradient (i_v). Thus, a positive value represents a downward gradient.

TABLE 4-5
VERTICAL HYDRAULIC GRADIENTS - JANUARY 4, 1996
WEST LAKE LANDFILL

Interval Monitored	Piezometer Pair	ΔH	ΔL	i_v
Shallow Alluvium to Intermediate Alluvium	PZ-302-AS/PZ-302-AI	431.34-431.27	432.40-412.50	0.004
Shallow Alluvium to Intermediate Alluvium	PZ-304-AS/PZ-304-AI	431.13-431.16	429.40-407.70	-0.008
Shallow Alluvium to Deep Alluvium	PZ-113-AS/PZ-113-AD	431.07-431.03	425.92-356.36	0.006
Shallow Alluvium to Deep Alluvium	PZ-300-AS/PZ-300-AD	434.11-432.12	433.70-408.60	0.08
Shallow Alluvium to St. Louis/Salem	PZ-114-AS/PZ-115-SS	431.20-414.34	424.78-370.03	0.31
Shallow Alluvium to St. Louis/Salem	PZ-205-AS/PZ-205-SS	430.98-420.28	416.88-367.56	0.22
Deep Alluvium to St. Louis/Salem	PZ-113-AD/PZ-113-SS	431.03-431.16	356.36-306.36	-0.003
Deep Alluvium to St. Louis/Salem	PZ-300-AD/PZ-300-SS	432.12-427.50	408.60-359.61	0.09
St. Louis/Salem to Deep Salem	PZ-100-SS/PZ-100-SD	413.63-355.04	400.57-244.65	0.38
St. Louis/Salem to Deep Salem	PZ-104-SS/PZ-104-SD	361.53-343.15	342.16-241.25	0.18
St. Louis/Salem to Deep Salem	PZ-106-SS/PZ-106-SD	343.70-341.52	300.75-265.75	0.06
Deep Salem to Keokuk	PZ-100-SD/PZ-100-KS	355.04-432.69	244.65-104.86	-0.56
Deep Salem to Keokuk	PZ-104-SD/PZ-104-KS	343.15-440.22	241.25-80.05	-0.60
Deep Salem to Keokuk	PZ-106-SD/PZ-106-KS	341.52-438.61	265.75-93.07	-0.56
Deep Salem to Keokuk	PZ-111-SD/PZ-111-KS	430.63-438.77	254.92-97.18	-0.05

NOTES:

ΔH = Head differential
ΔL = Distance differential
i_v = vertical gradient
(-) The negative sign is used in the context of this table to represent an upward gradient (i_v). Thus, a positive value represents a downward gradient.

TABLE 4-6
VERTICAL HYDRAULIC GRADIENTS - APRIL 3, 1996
WEST LAKE LANDFILL

Interval Monitored	Piezometer Pair	Δ H	Δ L	i_v
Shallow Alluvium to Intermediate Alluvium	PZ-302-AS/PZ-302-AI	430.03-426.75	432.40-412.50	0.16
Shallow Alluvium to Intermediate Alluvium	PZ-304-AS/PZ-304-AI	429.59-429.62	429.40-407.70	-0.0014
Shallow Alluvium to Deep Alluvium	PZ-113-AS/PZ-113-AD	429.48-429.62	425.92-356.36	-0.002
Shallow Alluvium to Deep Alluvium	PZ-300-AS/PZ-300-AD	434.02-430.63	433.70-408.60	0.14
Shallow Alluvium to St. Louis/Salem	PZ-114-AS/PZ-115-SS	429.93-414.31	424.78-370.03	0.28
Shallow Alluvium to St. Louis/Salem	PZ-205-AS/PZ-205-SS	429.85-419.11	416.88-367.56	0.22
Deep Alluvium to St. Louis/Salem	PZ-113-AD/PZ-113-SS	429.62-429.65	356.36-306.36	-0.0006
Deep Alluvium to St. Louis/Salem	PZ-300-AD/PZ-300-SS	430.63-426.58	408.60-359.61	0.08
St. Louis/Salem to Deep Salem	PZ-100-SS/PZ-100-SD	412.87-372.88	400.57-244.65	0.26
St. Louis/Salem to Deep Salem	PZ-104-SS/PZ-104-SD	362.99-360.25	342.16-241.25	0.03
St. Louis/Salem to Deep Salem	PZ-106-SS/PZ-106-SD	357.55-350.17	300.75-265.75	0.21
Deep Salem to Keokuk	PZ-100-SD/PZ-100-KS	372.88-435.71	244.65-104.86	-0.45
Deep Salem to Keokuk	PZ-104-SD/PZ-104-KS	360.25-442.94	241.25-80.05	-0.51
Deep Salem to Keokuk	PZ-106-SD/PZ-106-KS	350.17-440.50	265.75-93.07	-0.52
Deep Salem to Keokuk	PZ-111-SD/PZ-111-KS	428.90-440.13	254.92-97.18	-0.07

NOTES:

Δ H = Head differential
Δ L = Distance differential
i_v = vertical gradient
(-) The negative sign is used in the context of this table to represent an upward gradient (i_v). Thus, a positive value represents a downward gradient.

TABLE 4-7
VERTICAL HYDRAULIC GRADIENTS - MAY 3, 1996
WEST LAKE LANDFILL

Interval Monitored	Piezometer Pair	Δ H	Δ L	i_v
Shallow Alluvium to Intermediate Alluvium	PZ-302-AS/PZ-302-AI	431.26-431.10	432.40-412.50	0.008
Shallow Alluvium to Intermediate Alluvium	PZ-304-AS/PZ-304-AI	431.07-431.13	429.40-407.70	-0.003
Shallow Alluvium to Deep Alluvium	PZ-113-AS/PZ-113-AD	430.79-430.81	425.92-356.36	-0.003
Shallow Alluvium to St. Louis/Salem	PZ-114-AS/PZ-115-SS	431.60-423.51	424.78-370.03	0.15
Shallow Alluvium to St. Louis/Salem	PZ-205-AS/PZ-205-SS	430.68-420.13	416.88-367.56	0.21
Deep Alluvium to St. Louis/Salem	PZ-113-AD/PZ-113-SS	430.81-430.89	356.36-306.36	-0.002
St. Louis/Salem to Deep Salem	PZ-100-SS/PZ-100-SD	412.83-367.82	400.57-244.65	0.29
St. Louis/Salem to Deep Salem	PZ-104-SS/PZ-104-SD	376.44-370.88	342.16-241.25	0.06
St. Louis/Salem to Deep Salem	PZ-106-SS/PZ-106-SD	371.56-364.81	300.75-265.75	0.19
Deep Salem to Keokuk	PZ-100-SD/PZ-100-KS	367.82-435.56	244.65-104.86	-0.48
Deep Salem to Keokuk	PZ-104-SD/PZ-104-KS	370.88-443.35	241.25-80.05	-0.45
Deep Salem to Keokuk	PZ-106-SD/PZ-106-KS	364.81-440.68	265.75-93.07	-0.43
Deep Salem to Keokuk	PZ-111-SD/PZ-111-KS	429.00-440.16	254.92-97.18	-0.07

NOTES:

Δ H = Head differential
Δ L = Distance differential
i_v = vertical gradient
(-) The negative sign is used in the context of this table to represent an upward gradient (i_v). Thus, a positive value represents a downward gradient.

TABLE 4-8
VERTICAL HYDRAULIC GRADIENTS - JULY 12, 1996
WEST LAKE LANDFILL

Interval Monitored	Piezometer Pair	Δ H	Δ L	i_v
Shallow Alluvium to Intermediate Alluvium	PZ-302-AS/PZ-302-AI	434.12-434.05	432.40-412.50	0.0035
Shallow Alluvium to Intermediate Alluvium	PZ-304-AS/PZ-304-AI	434.14-434.20	429.40-407.70	-0.003
Shallow Alluvium to Deep Alluvium	PZ-113-AS/PZ-113-AD	434.39-434.35	425.92-356.36	0.0006
Shallow Alluvium to St. Louis/Salem	PZ-114-AS/PZ-115-SS	434.46-421.85	424.78-370.03	0.23
Shallow Alluvium to St. Louis/Salem	PZ-205-AS/PZ-205-SS	433.71-422.97	416.88-367.56	0.22
Deep Alluvium to St. Louis/Salem	PZ-113-AD/PZ-113-SS	434.35-434.46	356.36-306.36	-0.002
St. Louis/Salem to Deep Salem	PZ-100-SS/PZ-100-SD	412.94-367.04	400.57-244.65	0.29
St. Louis/Salem to Deep Salem	PZ-104-SS/PZ-104-SD	371.10-367.77	342.16-241.25	0.03
St. Louis/Salem to Deep Salem	PZ-106-SS/PZ-106-SD	368.46-367.31	300.75-265.75	0.03
Deep Salem to Keokuk	PZ-100-SD/PZ-100-KS	367.04-439.35	244.65-104.86	-0.52
Deep Salem to Keokuk	PZ-104-SD/PZ-104-KS	367.77-447.40	241.25-80.05	-0.49
Deep Salem to Keokuk	PZ-106-SD/PZ-106-KS	367.31-444.46	265.75-93.07	-0.45
Deep Salem to Keokuk	PZ-111-SD/PZ-111-KS	433.46-443.66	254.92-97.18	-0.06

NOTES:

Δ H = Head differential
Δ L = Distance differential
i_v = vertical gradient
(-) The negative sign is used in the context of this table to represent an upward gradient (i_v). Thus, a positive value represents a downward gradient.

TABLE 4-9
SUMMARY OF PACKER TESTING RESULTS
KEOKUK FORMATION
WEST LAKE LANDFILL

BOREHOLE	GROUND SURFACE ELEVATION	KEOKUK TEST INTERVAL (depth below ground surface)	HYDRAULIC CONDUCTIVITY	
			cm/sec	ft/min
PZ-100-KS	483.8	366.0-391.0	7.6E-7	1.5E-6
		377.0-391.0	1.4E-6	2.7E-6
PZ-104-KS	482.3	366.0-371.0	4.0E-6	7.9E-6
		360.0-408.0	5.7E-6	1.1E-5
		390.0-408.0	1.3E-5	2.6E-5
PZ-106-KS	460.8	357.0-362.0	2.8E-5	5.5E-5
		346.0-374.0	2.2E-5	4.3E-5
		364.0-374.0	1.7E-5	3.4E-5
PZ-111-KS	459.2	343.0-348.0	2.5E-5	4.9E-5
		355.0-360.0	4.3E-5	8.5E-5
		343.0-368.0	2.1E-5	4.1E-5
GEOMETRIC MEAN			**9.7E-6**	**1.9E-5**

TABLE 4-10
SUMMARY OF PACKER TESTING RESULTS
WARSAW FORMATION
WEST LAKE LANDFILL

BOREHOLE	GROUND SURFACE ELEVATION	WARSAW TEST INTERVAL (depth below ground surface)	HYDRAULIC CONDUCTIVITY cm/sec	HYDRAULIC CONDUCTIVITY ft/min
PZ-100-KS	483.8	290.0-295.0	5.6E-5	1.1E-4
		265.0-357.6	5.3E-6	1.0E-5
PZ-104-KS	482.3	287.0-292.0	2.7E-6	5.3E-6
		343.0-348.0	1.9E-6	3.7E-6
		270.0-290.0	4.4E-6	8.7E-7
		290.0-320.0	7.1E-7	1.4E-6
		320.0-358.3	3.4E-6	6.6E-7
PZ-106-KS	460.8	215.0-220.0	2.6E-7	5.1E-7
		237.0-242.0	2.4E-6	4.8E-6
		301.0-346.4	3.3E-5	6.6E-5
PZ-111-KS	459.2	221.0-226.0	9.5E-7	1.9E-6
		226.0-231.0	1.7E-6	3.3E-6
		260.0-265.0	2.0E-6	3.8E-6
		220.0-260.0	1.3E-6	2.5E-6
		260.0-290.0	1.1E-6	2.2E-6
		290.0-343.7	3.1E-6	6.1E-6
GEOMETRIC MEAN			**2.6E-6**	**3.8E-6**

cm/sec = centimeters per second
ft/min = feet per minute

TABLE 4-11
SUMMARY OF PACKER TESTING RESULTS
SALEM FORMATION
WEST LAKE LANDFILL

BOREHOLE	TEST DEPTH	HYDRAULIC CONDUCTIVITY cm/sec	HYDRAULIC CONDUCTIVITY ft/min
PZ-100-KS	195.0-200.0	3.9E-6	7.7E-6
	220.0-225.0	2.1E-6	4.1E-6
PZ-104-SD	208.0-213.0	8.4E-6	1.7E-5
	162.0-252.5	4.9E-6	9.7E-6
	235.0-252.5	3.2E-7	6.4E-7
PZ-106-SD	148.0-153.0	4.5E-6	8.8E-6
	140.0-201.0	2.5E-5	5.0E-5
	187.0-201.0	1.8E-7	3.5E-7
PZ-111-SD	127.0-210.0	1.3E-6	2.6E-6
	162.0-167.0	7.9E-7	1.5E-6
	195.0-200.0	5.8E-8	1.1E-7
	140.0-210.0	3.3E-6	6.4E-6
	175.0-210.0	1.2E-6	2.4E-6
GEOMETRIC MEAN		**1.6E-6**	**3.2E-6**

TABLE 4-12
SUMMARY OF PACKER TESTING RESULTS
ST. LOUIS FORMATION
WEST LAKE LANDFILL

BOREHOLE	TEST DEPTH	HYDRAULIC CONDUCTIVITY		COMMENTS
		cm/sec	ft/min	
PZ-100-KS	37.3-42.3	7.5E-4	1.5E-3	Unsaturated
	50.0-55.0	3.3E-6	6.6E-6	Unsaturated
	110.0-115.0	3.7E-7	7.2E-7	Saturated
PZ-104-SD	50.0-55.0	2.9E-6	5.7E-6	Unsaturated
	113.0-118.0	1.5E-7	2.9E-7	Unsaturated
PZ-106-SD	42.0-47.0	6.0E-6	1.2E-5	Unsaturated
	61.0-66.0	2.1E-6	4.1E-6	Unsaturated
PZ-111-SD	125.0-130.0	5.4E-7	1.1E-6	Saturated
	105.0-127.0	4.4E-6	8.6E-6	Saturated
GEOMETRIC MEAN		**4.9E-6**	**9.6E-6**	Unsaturated
GEOMETRIC MEAN		**1.6E-6**	**3.2E-6**	Saturated

TABLE 4-13
SUMMARY OF SLUG TEST RESULTS
WEST LAKE LANDFILL

PIEZOMETER	HYDRAULIC CONDUCTIVITY							
	HVORSLEV		BOUWER & RICE		COOPER PAPADOPULOS BEST FIT		MEAN VALUE OF HVORSLEV & BOUWER AND RICE	
	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min
SHALLOW ALLUVIAL PIEZOMETERS								
PZ-112-AS-RH1	1.9E-03	3.7E-03	1.1E-03	2.2E-03	NA	NA	1.5E-03	3.0E-03
PZ-112-AS-FH1	3.0E-03	5.9E-03	1.7E-03	3.3E-03	NA	NA	2.4E-03	4.6E-03
PZ-113-AS-RH1	1.4E-02	2.8E-02	5.3E-02	1.0E-01	NA	NA	3.4E-02	6.6E-02
PZ-113-AS-FH1	8.0E-03	1.6E-02	5.1E-03	1.0E-02	NA	NA	6.6E-03	1.3E-02
PZ-114-AS-FH1	3.1E-03	6.1E-03	1.7E-03	3.3E-03	NA	NA	2.4E-03	4.7E-03
PZ-114-AS-FH2	4.5E-03	8.9E-03	2.7E-03	5.3E-03	NA	NA	3.6E-03	7.1E-03
PZ-205-AS	6.0E-04	1.2E-03	4.4E-04	8.7E-04	NA	NA	5.2E-04	1.0E-03
PZ-207-AS	7.6E-03	1.5E-02	4.8E-03	9.4E-03	NA	NA	6.2E-03	1.2E-02
PZ-300-AS-FH[2]	5.8E-04	1.1E-03	NA	NA	NA	NA	5.8E-04	1.1E-03
PZ-300-AS-RH	7.1E-04	1.4E-03	2.1E-03	4.1E-03	NA	NA	1.4E-03	2.8E-03
PZ-302-AS-FH[2]	1.1E-04	2.2E-04	NA	NA	NA	NA	1.1E-04	2.2E-04
PZ-302-AS-RH	1.2E-04	2.4E-04	NA	NA	NA	NA	1.2E-04	2.4E-04
PZ-303-AS-FH1[2]	4.0E-04	7.9E-04	NA	NA	NA	NA	4.0E-04	7.9E-04
PZ-303-AS-FH2[2]	6.0E-04	1.2E-03	NA	NA	NA	NA	6.0E-04	1.2E-03
PZ-303-AS-RH	3.7E-03	7.3E-03	1.5E-02	3.0E-02	NA	NA	9.4E-03	1.8E-02
PZ-304-AS-FH[2]	8.7E-04	1.7E-03	NA	NA	NA	NA	8.7E-04	1.7E-03
PZ-304-AS-RH	5.9E-03	1.2E-02	1.8E-02	3.5E-02	NA	NA	1.2E-02	2.4E-02
GEOMETRIC MEAN	**2.5E-03**	**5.0E-03**	**3.9E-03**	**7.6E-03**	**NA**	**NA**	**2.9E-03**	**5.8E-03**

TABLE 4-13
SUMMARY OF SLUG TEST RESULTS
WEST LAKE LANDFILL

PIEZOMETER	HYDRAULIC CONDUCTIVITY							
	HVORSLEV		BOUWER & RICE		COOPER PAPADOPULOS BEST FIT		MEAN VALUE OF HVORSLEV & BOUWER AND RICE	
	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min
INTERMEDIATE ALLUVIAL PIEZOMETERS								
PZ-302-AI-FH	1.5E-02	3.0E-02	9.8E-03	1.9E-02	NA	NA	1.2E-02	2.4E-02
PZ-302-AI-RH	1.5E-02	3.0E-02	1.0E-02	2.0E-02	NA	NA	1.3E-02	2.5E-02
PZ-304-AI-FH	2.4E-02	4.7E-02	1.7E-02	3.3E-02	NA	NA	2.1E-02	4.0E-02
PZ-305-AI-FH[1]	1.8E-02	3.5E-02	1.4E-02	2.8E-02	NA	NA	1.6E-02	3.1E-02
PZ-305-AI-FH[2]	1.9E-04	3.7E-04	1.7E-04	3.3E-04	NA	NA	1.8E-04	3.5E-04
GEOMETRIC MEAN	**1.8E-02**	**3.5E-02**	**1.2E-02**	**2.3E-02**	**NA**	**NA**	**1.5E-02**	**2.9E-02**
DEEP ALLUVIAL PIEZOMETER								
PZ-113-AD-FH1	1.8E-03	3.5E-03	1.5E-03	3.0E-03	NA	NA	1.7E-03	3.2E-03
PZ-113-AD-FH2	1.9E-03	3.7E-03	1.4E-03	2.8E-03	NA	NA	1.7E-03	3.2E-03
PZ-300-AD-FH	3.7E-04	7.3E-04	2.7E-04	5.3E-04	NA	NA	3.2E-04	6.3E-04
PZ-300-AD-RH	1.6E-04	3.1E-04	1.1E-04	2.2E-04	NA	NA	1.4E-04	2.7E-04
GEOMETRIC MEAN	**6.7E-04**	**1.3E-03**	**5.0E-04**	**9.8E-04**	**NA**	**NA**	**5.9E-04**	**1.2E-03**

TABLE 4-13
SUMMARY OF SLUG TEST RESULTS
WEST LAKE LANDFILL

PIEZOMETER	HYDRAULIC CONDUCTIVITY							
	HVORSLEV		BOUWER & RICE		COOPER PAPADOPULOS BEST FIT		MEAN VALUE OF HVORSLEV & BOUWER AND RICE	
	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min
SHALLOW ST. LOUIS/SALEM PIEZOMETERS								
PZ-100-SS	1.0E-07	2.0E-07	5.7E-08	1.1E-07	NA	NA	7.9E-08	1.5E-07
PZ-101-SS	8.6E-07	1.7E-06	5.1E-07	1.0E-06	NA	NA	6.9E-07	1.3E-06
PZ-102R-SS	4.7E-08	9.3E-08	3.0E-08	5.9E-08	NA	NA	3.9E-08	7.6E-08
PZ-103-SS	8.4E-07	1.7E-06	1.7E-06	3.3E-06	NA	NA	1.3E-06	2.5E-06
PZ-104-SS	6.0E-07	1.2E-06	1.3E-06	2.6E-06	NA	NA	9.5E-07	1.9E-06
PZ-105-SS	3.5E-06	6.9E-06	8.5E-06	1.7E-05	NA	NA	6.0E-06	1.2E-05
PZ-106-SS	3.9E-06	7.7E-06	2.5E-06	4.9E-06	NA	NA	3.2E-06	6.3E-06
PZ-107-SS	1.6E-06	3.1E-06	1.2E-06	2.4E-06	NA	NA	1.4E-06	2.8E-06
PZ-108-SS	6.3E-07	1.2E-06	4.3E-07	8.5E-07	NA	NA	5.3E-07	1.0E-06
PZ-109-SS	1.8E-07	3.5E-07	8.7E-08	1.7E-07	NA	NA	1.3E-07	2.6E-07
PZ-110-SS[1]	1.6E-06	3.1E-06	8.9E-07	1.8E-06	NA	NA	1.2E-06	2.5E-06
PZ-113-SS	5.2E-06	1.0E-05	4.9E-06	9.6E-06	NA	NA	5.1E-06	9.9E-06
PZ-115-SS	2.9E-05	5.7E-05	2.4E-05	4.7E-05	NA	NA	2.7E-05	5.2E-05
PZ-116-SS	2.9E-08	5.7E-08	1.7E-08	3.3E-08	NA	NA	2.3E-08	4.5E-08
PZ-200-SS	1.5E-06	3.0E-06	2.8E-06	5.5E-06	NA	NA	2.2E-06	4.2E-06
PZ-201-SS	3.3E-05	6.5E-05	5.4E-05	1.1E-04	NA	NA	4.4E-05	8.6E-05
PZ-201A-SS	1.3E-07	2.6E-07	8.3E-08	1.6E-07	NA	NA	1.1E-07	2.1E-07
PZ-202-SS	3.0E-03	5.9E-03	2.5E-03	4.9E-03	NA	NA	2.8E-03	5.4E-03
PZ-204-SS	1.8E-06	3.5E-06	2.8E-06	5.5E-06	NA	NA	2.3E-06	4.5E-06

TABLE 4-13
SUMMARY OF SLUG TEST RESULTS
WEST LAKE LANDFILL

PIEZOMETER	HYDRAULIC CONDUCTIVITY							
	HVORSLEV		BOUWER & RICE		COOPER PAPADOPULOS BEST FIT		MEAN VALUE OF HVORSLEV & BOUWER AND RICE	
	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min
SHALLOW ST. LOUIS/SALEM PIEZOMETERS--Continued								
PZ-204A-SS	3.5E-07	6.9E-07	2.3E-07	4.5E-07	NA	NA	2.9E-07	5.7E-07
PZ-205-SS	4.4E-07	8.7E-07	3.9E-07	7.7E-07	NA	NA	4.2E-07	8.2E-07
PZ-206-SS	1.8E-05	3.5E-05	1.1E-05	2.2E-05	NA	NA	1.5E-05	2.9E-05
PZ-208-SS	4.3E-07	8.5E-07	2.7E-07	5.3E-07	NA	NA	3.5E-07	6.9E-07
PZ-300-SS	9.0E-07	1.8E-06	7.7E-07	1.5E-06	NA	NA	8.4E-07	1.6E-06
PZ-301-SS[1]	7.5E-07	1.5E-06	NA	NA	NA	NA	7.5E-07	1.5E-06
GEOMETRIC MEAN	**1.3E-06**	**2.6E-06**	**1.2E-06**	**2.4E-06**	**NA**	**NA**	**1.3E-06**	**2.6E-06**
DEEP SALEM PIEZOMETERS								
PZ100-SD	9.1E-07	1.8E-06	6.4E-07	1.3E-06	NA	NA	7.8E-07	1.5E-06
PZ-104-SD	1.8E-05	3.5E-05	1.2E-05	2.3E-05	NA	NA	1.5E-05	2.9E-05
PZ-106-SD	3.0E-07	5.9E-07	1.6E-07	3.1E-07	NA	NA	2.3E-07	4.5E-07
PZ-111-SD	1.0E-07	2.0E-07	6.8E-08	1.3E-07	NA	NA	8.4E-08	1.7E-07
GEOMETRIC MEAN	**8.4E-07**	**1.6E-06**	**5.4E-07**	**1.1E-06**	**NA**	**NA**	**6.9E-07**	**1.4E-06**

TABLE 4-13
SUMMARY OF SLUG TEST RESULTS
WEST LAKE LANDFILL

PIEZOMETER	HYDRAULIC CONDUCTIVITY							
	HVORSLEV		BOUWER & RICE		COOPER PAPADOPULOS BEST FIT		MEAN VALUE OF HVORSLEV & BOUWER AND RICE	
	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min	cm/sec	ft/min
KEOKUK PIEZOMETERS								
PZ-100-KS	NA	NA	NA	NA	6.0E-07	1.2E-06	NA	NA
PZ-104-KS	NA	NA	NA	NA	2.5E-06	4.9E-06	NA	NA
PZ-106-KS	NA	NA	NA	NA	3.1E-06	6.1E-06	NA	NA
PZ-111-KS	NA	NA	NA	NA	3.8E-06	7.5E-06	NA	NA
GEOMETRIC MEAN	**NA**	**NA**	**NA**	**NA**	**2.1E-06**	**4.0E-06**	**NA**	**NA**

NOTES:

cm/sec = centimeters per second

ft/min = feet per minute

NA = Not Applicable. These analyses were not performed and/or were inapplicable for data from these boreholes.

[1] Slug tests conducted before piezometer reached equilibrium; data presented but not included in geometric means.

[2] Falling head slug tests conducted within sand pack zone of well; data presented but not included in geometric means.

TABLE 4-14
HORIZONTAL GROUNDWATER VELOCITIES
WEST LAKE LANDFILL

Formation / **Hydraulic Conductivity**	**Gradient (ft/ft)**	**Effective Porosity** 0.10	0.20	0.30
		Velocity (ft/yr)		
Unconsolidated Materials K= 1.0×10^{-4} cm/sec	0.0014	NA	NA	0.5
St. Louis/Upper Salem K= 1.1×10^{-6} cm/sec	0.049	0.6	0.3	NA
	0.48	5.0	3.0	NA
Keokuk K = 4.5×10^{-6} cm/sec	0.0015	0.07	0.03	NA
	0.0036	0.2	0.1	NA

NOTE: The hydraulic conductivity (K) values reported above are the mean of saturated zone slug test and saturated zone packer test results in the respective bedrock formations, and the mean of the shallow and deep alluvial piezometer slug tests in the unconsolidated materials.

NA = Not applicable. Horizontal groundwater velocities were not calculated for these effective porosities.

TABLE 4-15
HISTORICAL PRECIPITATION SURVEY
WEST LAKE LANDFILL

Year	Precipitation (inches)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1961	0.39	2.06	4.75	3.47	7.25	3.67	6.20	1.88	4.01	2.67	2.90	1.95	41.20
1962	3.56	2.53	3.00	2.52	2.44	4.75	5.49	2.29	2.63	2.70	0.71	1.99	34.61
1963	0.74	0.25	5.54	1.98	4.77	3.87	1.37	2.55	1.13	2.85	2.90	0.67	28.62
1964	1.70	2.30	3.84	4.99	2.68	2.73	4.25	2.39	1.47	0.73	3.84	1.24	32.16
1965	2.51	1.16	2.34	3.67	1.38	3.03	3.17	3.59	3.00	0.46	0.78	3.17	28.26
1966	0.65	4.12	1.09	6.03	4.59	1.59	1.26	3.72	2.15	2.18	2.47	2.49	32.34
1967	2.89	1.72	2.77	3.40	4.73	4.46	3.84	1.36	4.33	3.45	2.15	6.20	41.30
1968	1.86	1.09	2.06	1.48	6.78	0.90	3.92	1.60	3.74	0.69	5.74	2.63	32.49
1969	3.61	2.04	2.47	4.01	2.11	8.65	7.08	0.52	5.03	5.77	0.44	1.99	43.72
1970	0.22	0.64	2.17	9.09	2.04	5.08	0.60	6.44	5.54	2.21	0.77	1.40	36.20
1971	0.66	3.08	1.81	1.65	5.66	2.43	4.70	0.08	3.98	1.51	1.67	6.50	33.73
1972	0.77	0.74	2.93	4.49	1.02	1.19	3.10	2.69	6.21	1.47	5.59	3.54	33.74
1973	1.40	1.04	5.81	4.25	3.92	4.23	2.85	2.46	3.52	2.33	3.65	4.36	39.82
1974	3.51	4.17	2.58	2.40	5.90	3.45	0.90	5.05	2.50	1.51	3.15	1.71	36.83
1975	5.38	3.59	4.08	4.56	3.23	3.78	2.56	5.44	2.48	0.21	2.62	2.28	40.21
1976	0.83	1.08	4.28	1.37	3.90	2.32	2.28	1.27	0.90	3.37	0.73	1.13	23.46
1977	2.38	2.47	6.28	0.99	2.13	5.47	4.28	5.34	3.64	3.76	4.33	2.34	43.41
1978	1.70	1.60	6.67	3.21	3.69	2.39	6.03	0.76	3.10	2.28	4.47	1.81	37.71
1979	1.95	1.48	3.63	7.47	1.62	1.67	3.67	2.26	T	1.81	2.07	1.85	29.48
1980	0.63	1.54	3.98	1.54	3.40	2.19	3.56	2.72	3.12	2.89	1.25	0.66	27.48
1981	0.64	2.18	2.97	3.40	6.79	5.82	10.71	3.31	1.17	3.81	2.71	2.01	45.52
1982	4.90	1.37	2.88	2.55	4.85	5.96	7.91	5.27	5.27	2.30	3.89	7.82	54.97
1983	0.72	0.95	3.54	7.30	6.32	4.32	1.23	2.24	1.24	5.40	7.79	3.75	44.80
1984	0.84	3.43	5.37	6.29	5.19	2.74	0.76	0.64	8.88	7.12	5.50	4.89	51.65
1985	0.53	3.77	5.18	3.60	3.30	9.43	5.23	3.66	0.43	1.96	9.95	3.69	50.73
1986	0.10	4.68	1.22	1.23	2.42	4.43	2.61	2.22	7.99	5.34	1.58	1.06	34.88
1987	1.98	1.40	2.16	1.74	2.00	3.59	5.04	5.56	1.62	1.74	4.09	7.46	38.38
1988	3.30	2.27	4.73	1.15	1.44	1.97	3.02	2.31	1.99	1.86	6.65	3.24	33.93
1989	2.58	1.43	4.53	2.10	4.11	2.34	4.59	3.00	1.69	0.95	0.59	0.69	28.60
1990	1.42	3.53	2.66	3.07	9.59	3.02	3.34	2.84	0.78	4.96	3.36	6.52	45.09
Record Mean	2.14	2.29	3.35	3.67	4.11	4.06	3.41	2.95	3.14	2.72	2.80	2.36	37.02

Notes: T=Trace
Station location: St. Louis/Lambert International Airport
Source: Gale, 1992.

TABLE 4-16
HISTORICAL RIVER STAGE SUMMARY
WEST LAKE LANDFILL

Month	Year												Average
	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Stage
October		20.95	30.26	12.61	10.06	10.61		9.68	12.04	23.47	11.68	15.30	15.67
November		15.26	22.83	13.32	10.82	8.51	7.64	8.72				15.29	12.80
December	15.86		20.64	16.75	8.96		7.82	10.37		17.41		12.66	13.81
January		16.20		15.20	13.96	9.17		11.07	9.23		13.55	12.59	12.62
February		16.09	16.62	15.76	14.55	9.39	10.53	11.03	10.94	16.58	15.08	12.94	13.59
March		24.09	16.02	20.70	15.67	11.88	16.22		12.63	20.84		13.16	16.80
April		20.40	18.36	23.63	17.90	12.43	16.20		16.56	25.05		17.33	18.65
May		19.16	22.31	19.86	13.89	10.95	23.79	19.36	13.37	24.91	22.80	29.85	20.02
June		22.03	18.60	18.57	10.99	12.36	24.43	17.09	12.63		19.81	29.49	18.60
July		15.40	21.17	17.61	10.51	11.24	17.24	12.21	16.74	33.89		24.06	18.01
August		16.30	15.91	15.21	10.39	11.78	15.03	9.78		31.38		19.60	16.15
September		14.71		15.15	10.61	17.03	11.78	10.04	14.70	27.22	12.12	15.79	14.92
Average	15.86	18.23	20.27	17.03	12.36	11.40	15.07	11.94	13.20	24.53	15.84	18.17	15.97

Notes:

River Stage Data based on Missouri River St. Charles (Mile 29) Gauging Station, 1984 through 1995. All values provided in feet.
Blank cell means data not provided or incomplete.
Data provided by USGS Water Resources Division, Rolla, MO.

TABLE 6-1

AQUEOUS SAMPLE PARAMETER LIST

PARAMETER	ANALYTICAL METHOD[1] Groundwater	HEALTH-BASED CRITERIA[2] Limit	Unit
RCRA SUBTITLE D APPENDIX I METALS			
Antimony	7041	6	ug/l
Arsenic	7060	3.8	ug/l
Barium	6010	2000	ug/l
Beryllium	6010	1.6	ug/l
Nickel	6010	100	ug/l
Selenium	7740	50	ug/l
Silver	6010	180	ug/l
Sodium	6010	-	-
Thallium	7841	2	ug/l
Vanadium	6010	260	ug/l
Zinc	6010	5000	ug/l
CONVENTIONALS			
Ammonia as Nitrogen	350.1	-	-
Boron	6010	3300	ug/l
Cadmium	6010	5	ug/l
Calcium	6010	-	-
Chemical Oxygen Demand (COD)	410.4	-	-
Chloride	325.2	250	mg/l
Chromium	6010	100	ug/l
Cobalt	6010	6600	ug/l
Copper	6010	1000	ug/l
Cyanide, Total	9010	200	ug/l
Fluoride	340.2	-	-
Hardness, Total (Calculated)	130.2	-	-
Iron	6010	-	-
Lead	7421	-	-
Magnesium	6010	-	-
Manganese	6010	-	-
Mercury	7470	2	ug/l
Nitrate/Nitrite	~~353~~	10	mg/l
	353.1		
Phosphorus, Total	365.2	-	-
Sulfate as SO_4	375.4	250	mg/l
Sulfide	9030	-	-
Total Dissolved Solids (TDS)	160.1	500	mg/l
Total Organic Carbon (TOC)	415.1	-	-
Total Petroleum Hydrocarbons	8015M	-	-
FIELD MEASUREMENTS			
pH (Field)	150.1	-	-
Specific Conductance (Field)	120.1	-	-
Groundwater Elevation	Field	-	-
Temperature	Field	-	-
RCRA SUBTITLE D APPENDIX I VOLATILE ORGANIC COMPOUNDS			
Acetone	8260	3700.0	ug/l
Acrylonitrile	8260	12.0	ug/l
Benzene	8260	5.0	ug/l
Bromochloromethane	8260	-	-
Bromodichloromethane	8260	17.0	ug/l
Bromoform (Tribromomethane)	8260	100.0	ug/l
Bromomethane (Methyl bromide)	8260	8.7	ug/l
Carbon disulfide	8260	21.0	ug/l
Carbon tetrachloride	8260	5.0	ug/l
Chlorobenzene	8260	39.0	ug/l
Chloroethane	8260	8600.0	ug/l
Chloroform (Trichloromethane)	8260	15.0	ug/l
Chloromethane (Methyl chloride)	8260	140.0	ug/l
1,2-Dibromo-3-chloropropane	8260	4.8	ug/l
Dibromochloromethane	8260	13.0	ug/l
1,2-Dibromoethane (Ethylene dibromide)	8260	0.075	ug/l
trans-1,4-Dichloro-2-butene	8260	-	-
1,2-Dichlorobenzene (o-DCB)	8260	370.0	ug/l
1,4-Dichlorobenzene (p-DCB)	8260	44.0	ug/l

Footnotes provided on page 4

TABLE 6-1

AQUEOUS SAMPLE PARAMETER LIST

PARAMETER	ANALYTICAL METHOD[1] Groundwater	HEALTH-BASED CRITERIA[2] Limit	Unit
1,1-Dichloroethane	8260	810.0	ug/l
1,2-Dichloroethane	8260	5.0	ug/l
1,1-Dichloroethene	8260	4.4	ug/l
cis-1,2-Dichloroethene	8260	61.0	ug/l
trans-1,2-Dichloroethene	8260	100.0	ug/l
1,2-Dichloropropane	8260	5.0	ug/l
cis-1,3-Dichloropropene	8260	-	-
trans-1,3-Dichloropropene	8260	-	-
Ethylbenzene	8260	700.0	ug/l
2-Hexanone	8260	-	-
Methyl ethyl ketone (2-Butanone)	8260	22000.0	ug/l
Methyl iodide (Iodomethane)	8260	-	-
Methyl isobutyl ketone (4-Methyl-2-pentanone)	8260	2900.0	ug/l
Methylene bromide	8260	61.0	ug/l
Methylene chloride	8260	5.0	ug/l
Styrene	8260	100.0	ug/l
1,1,1,2-Tetrachloroethane	8260	41.0	ug/l
1,1,2,2-Tetrachloroethane	8260	5.2	ug/l
Tetrachloroethene	8260	5.0	ug/l
Toluene	8260	750.0	ug/l
1,1,1-Trichloroethane	8260	200.0	ug/l
1,1,2-Trichloroethane	8260	5.0	ug/l
Trichloroethene	8260	5.0	ug/l
Trichlorofluoromethane (Freon 11)	8260	1300.0	ug/l
1,2,3-Trichloropropane	8260	0.15	ug/l
Vinyl acetate	8260	37000.0	ug/l
Vinyl chloride	8260	1.9	ug/l
Xylenes	8260	10000.0	ug/l
TCL SEMIVOLATILE ORGANIC COMPOUNDS			
Acenaphthene	8270	2200.0	ug/l
Acenaphthylene	8270	-	-
Anthracene	8270	11000	ug/l
Benzo(a)anthracene	~~8270~~	9.2	ug/l
	8310		
Benzo(a)pyrene	~~8270~~	0.2	ug/l
	8310		
Benzo(b)fluoranthene	~~8270~~	9.2	ug/l
	8310		
Benzo(ghi)perylene	8270	-	-
Benzo(k)fluoranthene	8270	92	ug/l
4-Bromophenyl phenyl ether	8270	2100	ug/l
Butyl benzyl phthalate	8270	7300	ug/l
Carbazole	8270	-	-
p-Chloro-m-cresol	8270	-	-
4-Chloroaniline	8270	150	ug/l
bis(2-Chloroethoxy)methane	8270	-	-
bis(2-Chloroethyl)ether	8270	0.92	ug/l
bis(2-Chloroisopropyl)ether	8270	96	ug/l
2-Chloronaphthalene	8270	2900	ug/l
2-Chlorophenol	8270	180	ug/l
4-Chlorophenyl phenyl ether	8270	-	-
Chrysene	8270	920	ug/l
m-Cresol	8270	1800	ug/l
o-Cresol	8270	1800	ug/l
p-Cresol	8270	180	ug/l
Dibenzo(a,h)anthracene	~~8270~~	0.92	ug/l
	8310		
Dibenzofuran	8270	-	-
3,3'-Dichlorobenzidine	8270	15	ug/l
2,4-Dichlorophenol	8270	110	ug/l
Diethyl phthalate	8270	29000	ug/l
Dimethyl phthalate	8270	370000	ug/l
2,4-Dimethylphenol	8270	730	ug/l
Di-n-butyl phthalate	8270	3700	ug/l

Footnotes provided on page 4

TABLE 6-1

AQUEOUS SAMPLE PARAMETER LIST

PARAMETER	ANALYTICAL METHOD[1] Groundwater	HEALTH-BASED CRITERIA[2] Limit	Unit
4,6-Dinitro-o-cresol	8270	-	-
2,4-Dinitrophenol	8270	73	ug/l
2,4-Dinitrotoluene	8270	73	ug/l
2,6-Dinitrotoluene	8270	37	ug/l
Di-n-octyl phthalate	8270	730	ug/l
bis(2-Ethylhexyl) phthalate	8270	6	ug/l
Fluoranthene	8270	1500	ug/l
Fluorene	8270	1500	ug/l
Hexachlorobenzene	~~8270~~	0.66	ug/l
	8080		
Hexachlorobutadiene	8270	14	ug/l
Hexachlorocyclopentadiene	8270	0.15	ug/l
Hexachloroethane	8270	75	ug/l
Indeno(1,2,3-cd)pyrene	~~8270~~	9.2	ug/l
	8310		
Isophorone	8270	7100	ug/l
2-Methylnaphthalene	8270	-	-
Naphthalene	8270	1500	ug/l
2-Nitroaniline	8270	2.2	ug/l
3-Nitroaniline	8270	110	ug/l
4-Nitroaniline	8270	110	ug/l
Nitrobenzene	8270	3.4	ug/l
2-Nitrophenol	8270	-	-
4-Nitrophenol	8270	2300	ug/l
N-Nitrosodi-n-propylamine	8270	0.96	ug/l
N-Nitrosodiphenylamine	8270	1400	ug/l
Pentachlorophenol	~~8270~~	1	ug/l
	8080		
Phenanthrene	8270	-	-
Phenol	8270	22000	ug/l
Pyrene	8270	1100	ug/l
1,2,4-Trichlorobenzene	8270	70	ug/l
2,4,5-Trichlorophenol	8270	3700	ug/l
2,4,6-Trichlorophenol	8270	610	ug/l
TCL PESTICIDES & PCBs			
Aldrin	8080	0.4	ug/l
alpha-BHC	8080	1.1	ug/l
beta-BHC	8080	3.7	ug/l
delta-BHC	8080	-	-
gamma-BHC (Lindane)	8080	0.2	ug/l
alpha-Chlordane	8080	2	ug/l
gamma-Chlordane	8080	2	ug/l
4,4'-DDD	8080	20	ug/l
4,4'-DDE	8080	20	ug/l
4,4'-DDT	8080	20	ug/l
Dieldrin	8080	0.42	ug/l
Endosulfan I	8080	-	-
Endosulfan II	8080	-	-
Endosulfan sulfate	8080	-	-
Endrin	8080	0.2	ug/l
Endrin aldehyde	8080	-	-
Endrin ketone	8080	-	-
Heptachlor	8080	0.23	ug/l
Heptachlor epoxide	8080	0.12	ug/l
Methoxychlor	8080	40	ug/l
Toxaphene	8080	3	ug/l
Aroclor-1016	8080	0.5	ug/l
Aroclor-1221	8080	0.5	ug/l
Aroclor-1232	8080	0.5	ug/l
Aroclor-1242	8080	0.5	ug/l
Aroclor-1248	8080	0.5	ug/l
Aroclor-1254	8080	0.5	ug/l
Aroclor-1260	8080	0.5	ug/l

Footnotes provided on page 4

TABLE 6-1

AQUEOUS SAMPLE PARAMETER LIST

NOTES:
1. Analytical methods may be determined by the actual concentration detected and the health-based criteria.
2. Health-based criteria will be used as detection limits for groundwater and surface water samples, and do not apply to leachate or seep samples. Actual quantitation limits provided by the laboratory will be equal to or less than the health-based criteria. The actual quantitation limits will be provided by the laboratory in the addendum to the QAPP.

- : Not applicable.
ug/L: micrograms per liter
mg/L: milligrams per liter
Groundwater samples will be analyzed for total and dissolved metals constituents.
Leachate and surface water samples will be analyzed for total metals constituents.
PCBs = Polychlorinated Biphenyls.
TCL = Target Compound List.

Footnotes provided on page 4

TABLE 6-2

GROUNDWATER SAMPLE RADIONUCLIDE PARAMETER LIST

PARAMETER	ANALYTICAL METHOD[2]	HEALTH-BASED CRITERIA[3]	
		LIMIT	UNITS
Gross Alpha, Total and Dissolved[1]	9310	5	pCi/L
Gross Beta, Total and Dissolved[1]	9310	1	--
Radium-226, Total and Dissolved[1]	9315A	5	pCi/L
Thorium-230, Total and Dissolved[1]	U-NAS-NS-3050	82.7	pCi/L
Uranium-234, 235, and 238, Total and Dissolved[1]	U-NAS-NS-3050	30	pCi/L

NOTES:

pCi/L = pico curies per liter

-- : Not applicable

1. Samples intended for dissolved constituent analysis will be filtered prior to adjusting sample pH for preservation.
2. Analytical methods may be determined by actual concentrations detected and the health-based criteria.
3. Actual quantitation limits provided by the laboratory will be equal to or less than the health-based criteria. The actual quantitation limits will be provided by the laboratory in the addendum to the QAPP.

TABLE 6-3

SEDIMENT SAMPLE PARAMETER LIST

PARAMETER	ANALYTICAL METHOD[1]	HEALTH-BASED CRITERIA LIMITS[2]	
		Limit	Units
RCRA SUBTITLE D APPENDIX I METALS			
Antimony	7041	410	mg/kg
Arsenic	7060	160	mg/kg
Barium	6010	72000	mg/kg
Beryllium	6010	67	mg/kg
Cadmium	6010	510	mg/kg
Chromium	6010	5100	mg/kg
Cobalt	6010	180000	mg/kg
Copper	6010	38000	mg/kg
Lead	7421	-	-
Nickel	6010	20000	mg/kg
Selenium	7740	5100	mg/kg
Silver	6010	5100	mg/kg
Sodium	6010	-	-
Thallium	7841	-	-
Vanadium	6010	7200	mg/kg
Zinc	6010	310000	mg/kg
CONVENTIONALS			
Boron	6010	92000	mg/kg
Calcium	6010	-	-
Iron	6010	-	-
Cyanide, Total	9010	20000	mg/kg
Magnesium	6010	-	-
Manganese	6010	-	-
Mercury	7470	310	mg/kg
Sulfide	9030	-	-
Total Petroleum Hydrocarbons	8015M	-	-
RCRA SUBTITLE D APPENDIX I VOLATILE ORGANIC COMPOUNDS			
Acetone	8260	100000	mg/kg
Acrylonitrile	8260	530	mg/kg
Benzene	8260	9900	mg/kg
Bromochloromethane	8260	-	-
Bromodichloromethane	8260	4600	mg/kg
Bromoform (Tribromomethane)	8260	36000	mg/kg
Bromomethane (Methyl bromide)	8260	1400	mg/kg
Carbon disulfide	8260	100000	mg/kg
Carbon tetrachloride	8260	2200	mg/kg
Chlorobenzene	8260	20000	mg/kg
Chloroethane	8260	410000	mg/kg
Chloroform (Trichloromethane)	8260	47000	mg/kg
Chloromethane (Methyl chloride)	8260	22000	mg/kg
1,2-Dibromo-3-chloropropane	8260	200	mg/kg
Dibromochloromethane	8260	3400	mg/kg
1,2-Dibromoethane (Ethylene dibromide)	8260	3.4	mg/kg
trans-1,4-Dichloro-2-butene	8260	-	-
1,2-Dichlorobenzene (o-DCB)	8260	92000	mg/kg
1,4-Dichlorobenzene (p-DCB)	8260	12000	mg/kg
1,1-Dichloroethane	8260	100000	mg/kg
1,2-Dichloroethane	8260	3100	mg/kg
1,1-Dichloroethene	8260	480	mg/kg
cis-1,2-Dichloroethene	8260	10000	mg/kg
trans-1,2-Dichloroethene	8260	20000	mg/kg
1,2-Dichloropropane	8260	4200	mg/kg
cis-1,3-Dichloropropene	8260	-	-
trans-1,3-Dichloropropene	8260	-	-
Ethylbenzene	8260	100000	mg/kg
2-Hexanone	8260	-	-
Methyl ethyl ketone (2-Butanone)	8260	610000	mg/kg
Methyl iodide (Iodomethane)	8260	-	-
Methyl isobutyl ketone (4-Methyl-2-pentanone)	8260	82000	mg/kg
Methylene bromide (Dibromomethane)	8260	10000	mg/kg

Footnotes provided on page 3

TABLE 6-3

SEDIMENT SAMPLE PARAMETER LIST

PARAMETER	ANALYTICAL METHOD[1]	HEALTH-BASED CRITERIA LIMITS[2]	
		Limit	Units
Methylene chloride (Dichloromethane)	8260	38000	mg/kg
Styrene	8260	200000	mg/kg
1,1,1,2-Tetrachloroethane	8260	11000	mg/kg
1,1,2,2-Tetrachloroethane	8260	1400	mg/kg
Tetrachloroethene	8260	5500	mg/kg
Toluene	8260	200000	mg/kg
1,1,1-Trichloroethane	8260	92000	mg/kg
1,1,2-Trichloroethane	8260	5000	mg/kg
Trichloroethene	8260	26000	mg/kg
Trichlorofluoromethane (Freon 11)	8260	310000	mg/kg
1,2,3-Trichloropropane	8260	41	mg/kg
Vinyl acetate	8260	100000	mg/kg
Vinyl chloride	8260	150	mg/kg
Xylenes	8260	100000	mg/kg
TCL SEMIVOLATILE ORGANIC COMPOUNDS			
Acenaphthene	8270	61000	mg/kg
Acenaphthylene	8270	-	-
Anthracene	8270	310000	mg/kg
Benzo(a)anthracene	8310	390	mg/kg
Benzo(a)pyrene	8310	39	mg/kg
Benzo(b)fluoranthene	8310	390	mg/kg
Benzo(ghi)perylene	8270	-	-
Benzo(k)fluoranthene	8270	3900	mg/kg
4-Bromophenyl phenyl ether	8270	59000	mg/kg
Butyl benzyl phthalate	8270	200000	mg/kg
Carbazole	8270	-	-
p-Chloro-m-cresol	8270	-	-
4-Chloroaniline	8270	4100	mg/kg
bis(2-Chloroethoxy)methane	8270	-	-
bis(2-Chloroethyl)ether	8270	260	mg/kg
bis(2-Chloroisopropyl)ether	8270	4100	mg/kg
2-Chloronaphthalene	8270	82000	mg/kg
2-Chlorophenol	8270	5100	mg/kg
4-Chlorophenyl phenyl ether	8270	-	-
Chrysene	8270	39000	mg/kg
m-Cresol	8270	51000	mg/kg
o-Cresol	8270	51000	mg/kg
p-Cresol	8270	5100	mg/kg
Dibenzo(a,h)anthracene	8310	39	mg/kg
Dibenzofuran	8270	-	-
1,3-Dichlorobenzene (m-DCB)	8270	91000	mg/kg
3,3'-Dichlorobenzidine	8270	640	mg/kg
2,4-Dichlorophenol	8270	3100	mg/kg
Diethyl phthalate	8270	820000	mg/kg
Dimethyl phthalate	8270	1000000	mg/kg
2,4-Dimethylphenol	8270	20000	mg/kg
Di-n-butyl phthalate	8270	100000	mg/kg
4,6-Dinitro-o-cresol	8270	-	-
2,4-Dinitrophenol	8270	2000	mg/kg
2,4-Dinitrotoluene	8270	2000	mg/kg
2,6-Dinitrotoluene	8270	1000	mg/kg
Di-n-octyl phthalate	8270	20000	mg/kg
bis(2-Ethylhexyl) phthalate	8270	20000	mg/kg
Fluoranthene	8270	41000	mg/kg
Fluorene	8270	41000	mg/kg
Hexachlorobenzene	8080	180	mg/kg
Hexachlorobutadiene	8270	3700	mg/kg
Hexachlorocyclopentadiene	8270	7200	mg/kg
Hexachloroethane	8270	20000	mg/kg
Indeno(1,2,3-cd)pyrene	8080	390	mg/kg
Isophorone	8270	300000	mg/kg
2-Methylnaphthalene	8270	-	-
Naphthalene	8270	41000	mg/kg

Footnotes provided on page 3

TABLE 6-3

SEDIMENT SAMPLE PARAMETER LIST

PARAMETER	ANALYTICAL METHOD[1]	HEALTH-BASED CRITERIA LIMITS[2]	
		Limit	Units
2-Nitroaniline	8270	61	mg/kg
3-Nitroaniline	8270	3100	mg/kg
4-Nitroaniline	8270	3100	mg/kg
Nitrobenzene	8270	510	mg/kg
2-Nitrophenol	8270	-	-
4-Nitrophenol	8270	63000	mg/kg
N-Nitrosodi-n-propylamine	8270	41	mg/kg
N-Nitrosodiphenylamine	8270	58000	mg/kg
Pentachlorophenol	8080	2400	mg/kg
Phenanthrene	8270	-	-
Phenol	8270	610000	mg/kg
Pyrene	8270	31000	mg/kg
1,2,4-Trichlorobenzene	8270	10000	mg/kg
2,4,5-Trichlorophenol	8270	100000	mg/kg
2,4,6-Trichlorophenol	8270	26000	mg/kg
TCL PESTICIDES & PCBs			
Aldrin	8080	17	mg/kg
alpha-BHC	8080	45	mg/kg
beta-BHC	8080	160	mg/kg
delta-BHC	8080	-	-
gamma-BHC (Lindane)	8080	220	mg/kg
alpha-Chlordane	8080	220	mg/kg
gamma-Chlordane	8080	220	mg/kg
4,4'-DDD	8080	1200	mg/kg
4,4'-DDE	8080	840	mg/kg
4,4'-DDT	8080	840	mg/kg
Dieldrin	8080	18	mg/kg
Endosulfan I	8080	-	-
Endosulfan II	8080	-	-
Endosulfan sulfate	8080	-	-
Endrin	8080	310	mg/kg
Endrin aldehyde	8080	-	-
Endrin ketone	8080	-	-
Heptachlor	8080	64	mg/kg
Heptachlor epoxide	8080	31	mg/kg
Methoxychlor	8080	5100	mg/kg
Toxaphene	8080	260	mg/kg
Aroclor-1016	8080	37	mg/kg
Aroclor-1221	8080	37	mg/kg
Aroclor-1232	8080	37	mg/kg
Aroclor-1242	8080	37	mg/kg
Aroclor-1248	8080	37	mg/kg
Aroclor-1254	8080	37	mg/kg
Aroclor-1260	8080	37	mg/kg

NOTES:

1. Analytical methods may be determined by actual concentrations detected and the health-based criteria.
2. Actual quantitation limits provided by the laboratory will be equal to or less than the health-based criteria. The actual quantitation limits will be provided by the laboratory in the addendum to the QAPP.

- : Not applicable
mg/kg: milligrams per kilogram
TCL: Target Compound List
PCBs: Polychlorinated Biphenyls

Footnotes provided on page 3

TABLE 6-4

PROPOSED SPLIT SAMPLE LOCATIONS
WEST LAKE LANDFILL

MEDIA	PROPOSED SPLIT SAMPLE LOCATIONS
Groundwater	Round 1 MW-103, PZ-303-AS, PZ-204A-SS Round 2 PZ-208-SS, PZ-304-AS, PZ-111-SD
Surface Water	SW-02
Sediment	SED-02
Leachate	LR-105 LCS-1